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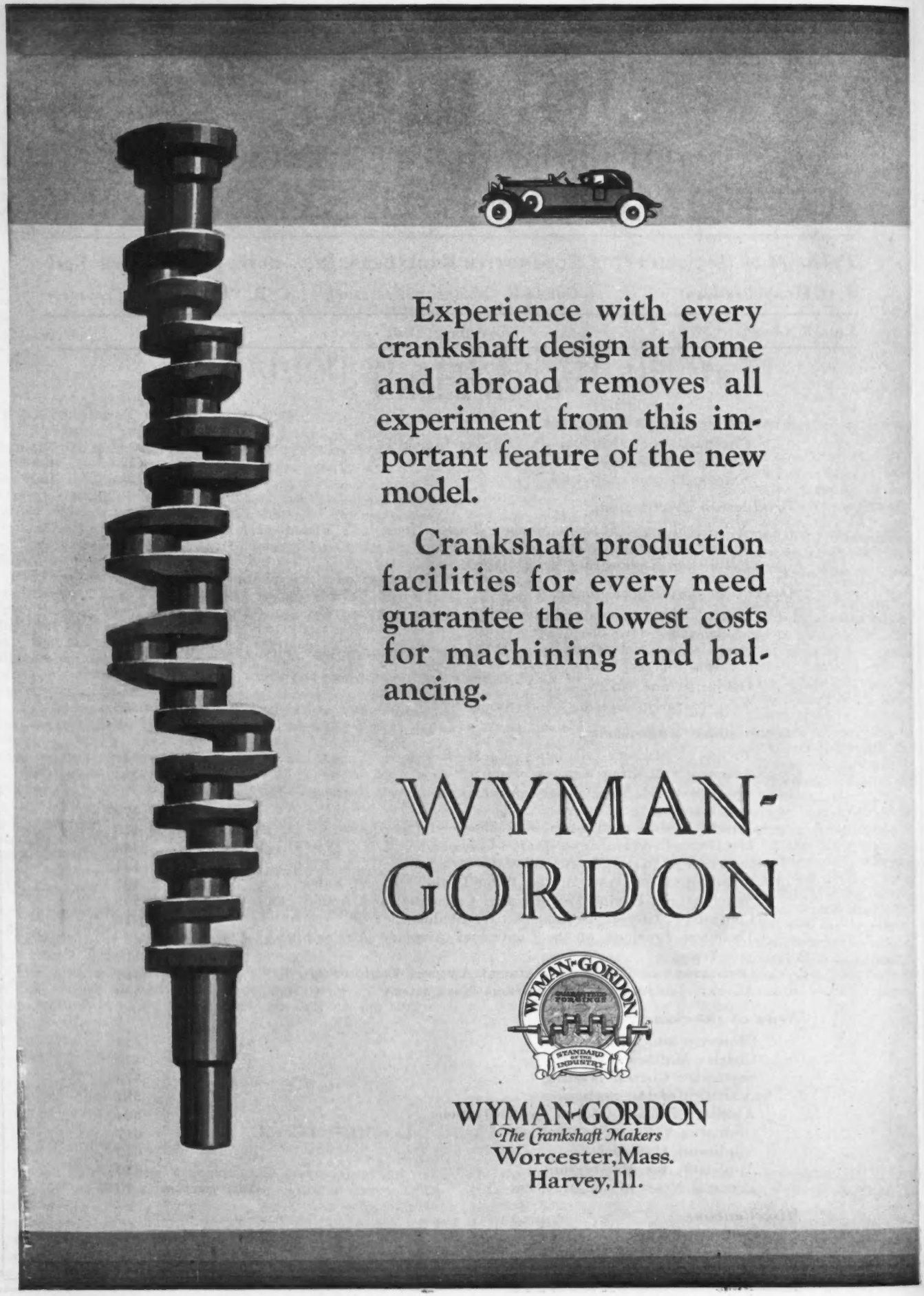
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Worcester, Mass.
Harvey, Ill.

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XXI November, 1927 No. 5

Chronicle and Comment

Death of Past-President Manly

THE passing of Past-President Manly was one of the direst blows the Society and the industry ever sustained. The work he did in engineering and in Society affairs was monumental. His loss will be felt greatly and is most deeply deplored, as set forth elsewhere in this issue.

Welcome to Detroit Super Charger

ANOTHER Section publication has made its advent and has been christened the *Detroit Super Charger*. Congratulations are offered by the godparent. In a statement announcing its appearance in the Sections family, Chairman E. W. Austin, of the Detroit Section Entertainment and Publicity Committee, states that it is the new messenger and is to be busy every month delivering advance information to the Section members. More information regarding it and the announcements in the first, the October, issue of the *Super Charger* is given in Activities of the Sections in this number of THE JOURNAL.

Society Represented at London Meetings

MEMBERS of the Society are attending the World Motor-Transport Congress, the Commercial Motor-Transport Exposition and sessions of the Institution of Automobile Engineers in London, England. this month.

N. D. Ballantine has prepared discussion for presentation at the Congress on the subject of the Necessity for Coordination of Rail and Road Transport. Past-President Horning and David Bacon will present papers at sessions of the Institution of Automobile Engineers. Mr. Bacon will discuss the Benefits of Coordination of Rail and Highway Transport. Mr. Horning will outline the Trend of Design in Motor-Trucks and Motorcoaches for Fleet Operation.

Theory Points Way to Speed Regulations

AUTOMOBILE speed regulation always has bristled with difficulties for both lawmakers and law enforcers. How fast may an automobile be permitted to go in the service of its owner? How slow must it be constrained to go in the interests of the safety of others using the highways? These are the conflicting questions.

Dr. H. C. Dickinson, chairman of the Research Committee of the Society, and C. F. Marvin, Jr., in a paper presented at the 1925 Semi-Annual Meeting, pointed out that other factors besides miles per hour should be considered in making speed regulations. Among these are the stopping-ability of the brakes and the condition and character of the highway traveled. The object of regulating the conduct of vehicles on the highway is, they said, not to prohibit speed but to promote safety, and they incorporated the principles they espoused in the following proposed rule:

> No vehicle shall be operated at a speed such that it cannot be stopped within the assured clear course ahead.

Closely following the spirit and even the phraseology of this suggestion, the State of Michigan has incorporated the following paragraph in its 1927 revision of laws relating to motor-vehicles:

> Any person driving a vehicle on a highway shall drive the same at a careful and prudent speed not greater than nor less than is reasonable and proper, having due regard to the traffic, surface and width of highway and of any other conditions then existing, and no person shall drive any vehicle upon a highway at a speed greater than will permit him to bring it to a stop *within the assured clear distance ahead.*

Perhaps this law may prove to be one of the opening events in a new era of motor-vehicle speed regulation.

Aircraft Operation and Maintenance

RAPID development of adequate methods of operating and maintaining aircraft is indicated by recent descriptions of systems now used and by numerous suggestions made to perfect organization to cope successfully with the problems in this new and increasingly extensive field, the confines of which are being enlarged by the extension of air-mail and of commercial-airplane service.

With reference to military aviation, C. M. Keys says in a special article on the next page that

> All governments are studying maintenance costs, and nearly all of them possess adequate tables showing cost per mile flown for all types of aircraft, taking in as an element of cost the writing off of original costs.

Further evidence of development is given by the operation and maintenance methods described in a paper by C. H. Biddlecombe, also printed in this issue; and a forthcoming paper by C. N. Montieth on major problems encountered in the operation of the Transcontinental Air-Mail line, which was presented at the Spokane session of the Aeronautic Meeting.

Trends in Military Airplanes

By C. M. KEYS[1]

THE character of aviation, as a whole, has changed entirely since the end of the war. In France, England and Italy in 1919, and in the United States in 1920 and subsequent years, I had a good opportunity to learn what the status of aviation really was at that time. In all these countries it was regarded as distinctly an adjunct of the military services. This was so much the case that nearly all the heads of commercial aviation in Europe were military officers. One found the impression general in military and naval circles in all these countries that aviation always had been and always would be a subordinate military art, like the building of torpedoes, battleships, or coast-defense guns.

Conditions are different these days. The advance of commercial aviation under the leadership of Germany, which was restrained by her benevolent enemies in the Treaty of Versailles from spending her money in military aviation and was thereby forced, willy-nilly, into becoming the world's leader in the development of commercial air pursuits, has changed all that very greatly, and the most definite trend in military aviation, even in the great countries of Europe, is to adapt itself to, and to cooperate with the development of commercial aviation. This is most striking in the smaller neutral countries of Europe, such as Denmark and Sweden. It is true only in part in Poland and in Italy.

In England there has been current distinct complaint on the part of the military people that all branches of the military service have been more or less held back by the fact that the development of purely military types of plane and engine has been sacrificed to some extent to the development of commercial types, especially of engines. At present there is a great awakening in England, due to the gigantic effort made by that country during the last 18 months to recover the Schneider Cup, and even more to constant criticism, both in the press and in Parliament, of the comparatively low performance of the Royal Air Force pursuit classes, both the military and the naval.

In Italy, France and England there has sprung up in the last year a very strong tendency toward high performance of the fighting planes, both at sea-level and at altitude. Supercharging of air-cooled and water-cooled engines is being pushed forward strongly but is hampered by the greatly increased cost of using supercharged engines, owing to the curtailment of engine life.

The new requirements of very high speed forced upon the military services of these three countries by the pressure of public opinion and the agitation of the pilots, seem to create a trend toward a division of the pursuit classes into three distinct subdivisions; namely, the normal pursuit squadron, equipped with air-cooled or low-compression water-cooled engines, as the case may be; great-altitude pursuit planes, using supercharged engines, and high-speed pursuit planes, using water-cooled engines. This seems to have made the pursuit program a somewhat complicated one, which can be solved only by a multiplicity of types, rather than by trying to standardize on one type. Undoubtedly, in this part of the program, standardization is dying out in Europe.

In bombers the trend seems altogether toward greater speed, ceiling and range, as well as greater load. One of the best Continental bombers, which created a sensation 2 years ago, has been revised by doubling the gasoline supply at the cost of decrease in bomber load. Two types recently laid down in England have cut both bomber load and range to get greater speed and ceiling. One cannot say that a universal trend can be traced in the bomber development, because here again, as in the case of the pursuit ships, the trend is distinctly toward diversification of types rather than toward standardization. Both England and France have a large number of contracts, and there seems to be no tendency to cut down the number. On the contrary, the development of new types is encouraged and the authorities seem quite willing to underwrite the undoubted extra cost of diversity, rather than to run the risk of developing a one-sided service. The slogan seems to be, bombers of distinct types for all uses, rather than a single design of general-utility bomber.

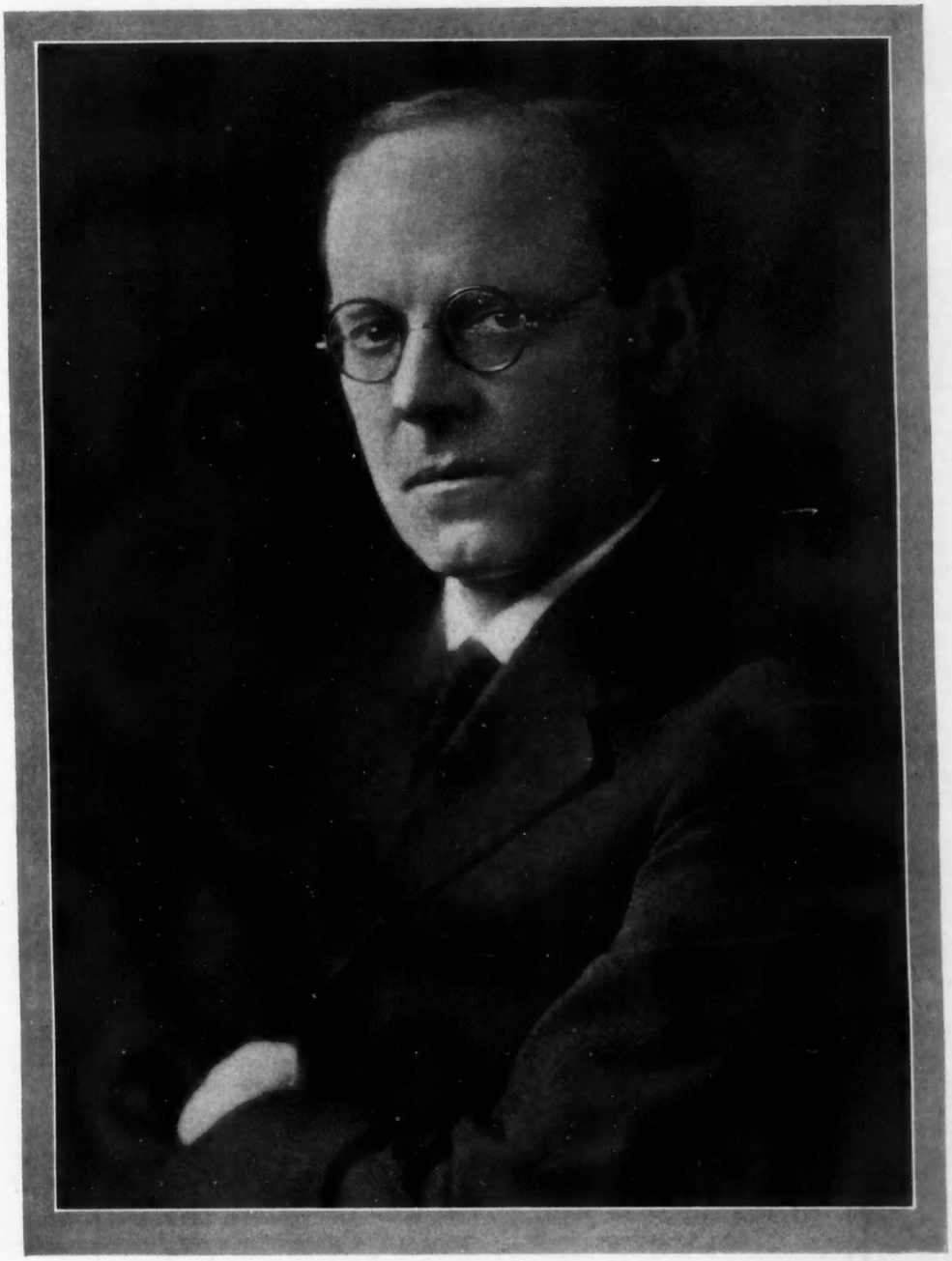
In two-place ships I have observed with something like astonishment a single order for 400 planes of a single general type for both military and naval use, some equipped with pontoons, some two-place, some three-place, and nearly all with water-cooled engines. This seems like a reaction from the general trend toward diversification of types, but it would be more illuminating if we had full details of all the sub-types that come under this one general order. It would not be surprising if 10 or 15 distinct classes of ship came out of this one block.

In nearly all lands the tendency in training planes is the same; namely, the continuance of the desire for a sturdy plane with an air-cooled engine. Here again one observes a sharp tendency toward diversification, with a multiplicity of types, consisting of advanced training-planes for attack, for observation, for pursuit and for other purposes; so that even the training fleet has ceased to be standardized. In this, as in all other branches, all governments are studying maintenance costs, and nearly all of them now possess adequate tables showing cost per mile flown for all types of ship, taking in as an element of cost the writing-off of original costs. On this basis rebuilt war-surplus machines have practically been eliminated from the programs of all first-class countries on the ground of excessive cost, as well as for the purpose of saving the lives of pilots.

A slight reaction seems to be under way in naval aeronautics in Europe, and possibly also in the United States, from the doctrine that all naval aviation is fleet aviation. An English officer, who a year ago could think of aviation only as an adjunct to the fleet, expressed the opinion to me last summer that all defensive naval aviation is likely to operate from shore bases in the next war. Both views probably are extreme, but it certainly seems true that naval authorities are beginning to realize that aviation in war-time will be in such volume and quantity that the aircraft cannot be carried around the world in ships, and that, so far as the Air Services are concerned, it will be much easier to defend a well-equipped coast

(*Concluded on p.* 596)

[1] A.S.A.E.—President, Curtiss Aeroplane & Motor Co., Inc., and chairman of the executive committee, National Air Transport, Inc., New York City.



C. M. KEYS

Meetings Calendar

Tractor and Stationary Engine Meeting
Dec. 1, 1927
Hotel Sherman, Chicago

Annual Dinner
Jan. 12, 1928
Hotel Astor, New York City

Annual Meeting
Jan. 24 to 27, 1928
Detroit

Sections Calendar

Buffalo Section Meeting—Nov. 1, 1927
Body Design—Alvin Carlson

Chicago Section Meeting—Nov. 8, 1927
Aviation Meeting—J. P. Porter and W. A. Jones

Cleveland Section Meeting—Nov. 14, 1927
Lacquer Surfaces—Construction, Adaptability and Use—Dr. C. D. Holley

Detroit Section Meeting—Nov. 7, 1927
Inspection trip through Ford Airport in the afternoon and papers on High Flying, by W. B. Stout, and the Latest Phases of Military Aviation, by Major Lamphier in the evening

Detroit Section Meeting—Nov. 21, 1927
Inspection trip through plant of U. S. Rubber Co. in the afternoon and paper on Production Progress and Tire Simplification, by B. J. Lemon in the evening

Indiana Section Meeting—Nov. 10, 1927
Inspection trip through plant of Delco-Remy Corporation and paper on Production by C. E. Wilson

Milwaukee Section Meeting—Nov. 2, 1927
The story of the Wright Engine—E. T. Jones

New England Section Meeting—Nov. 9, 1927
Precision Measurements in Production and Service—Warren Ames

Pennsylvania Section Meeting—Nov. 15, 1927
Recent Developments in Connection with Engine Lubrication—R. E. Wilson

Southern California Section Meeting—Nov. 4, 1927
Training Men for the Automotive Industry—John C. Beswick, H. A. Campion, Benjamin W. Johnson, and W. S. Kienholz

Aeronautic Meeting Story

Photo copyright by William E. Arthur

Full Report of Papers and Discussion by Leading Constructors and Government Representatives at Most Successful Gathering

Without question, the 1927 Aeronautic Meeting was the most successful aeronautic-engineering meeting ever held, said Henry M. Crane, when summarizing the 3-days' sessions in his introductory remarks as chairman of the last session on the afternoon of Thursday, Oct. 20, at the Waldorf-Astoria Hotel in New York City. This seemed to be the consensus of opinion of members attending the fourth annual Aeronautic Meeting of the Society, the success of which justified the decision of the Meetings Committee to hold the meeting for the first time separately from any other aeronautic event, such as the National Air Races.

The total attendance at the New York City sessions was 375, and the average attendance at the five sessions was 175. Including the attendance at the first official session of the meeting, which was held in Spokane, Wash., Sept. 23, and which was reported in the October issue of THE JOURNAL on p. 348, the total attendance of the 1927 Aeronautic Meeting exceeded 500.

The registration at the meeting, printed on p. 468 of this issue, shows that the meeting was national in scope and brought together leading aeronautical engineers and executives of the American industry. Public interest in the technical sessions was well proved by the way in which the newspapers in the Metropolitan area and, in fact, throughout the Country, recorded the interesting points brought out by the authors of the papers and by the discussers.

TRULY REPRESENTATIVE OF THE INDUSTRY

The very latest developments in aviation, and almost every problem of consequence in aeronautics, were dealt with in the papers, and the speakers were, as commented upon in an editorial in the *New York Times*, the best minds of the industry. Many of the papers presented at the New York City sessions are printed in full in this issue of THE JOURNAL. Others presented at Spokane and in New York City will appear as early as possible in subsequent issues. The unprinted papers presented at the October sessions are summarized, together with the discussion of them, in the following news account of the meeting.

Full credit for the success of the occasion is due to Edward P. Warner, chairman of the Aeronautic Meeting Committee, who not only took a very active part in planning the program, but also served as chairman of the second session and presented a paper, The Direct Application of Commercial Aircraft in the Naval Service, and was one of the leading discussers of a number of other papers. He was ably supported as chairman of the Aeronautic Meeting Committee by the other members of this committee; Lieut. E. E. Aldrin; H. M. Crane; E. T. Jones, second vice-president of the Society representing aviation engineering; Alexander Klemin; W. L. LePage; Lester D. Seymour; William B. Stout, and J. A. C. Warner.

In his summarization of the sessions, Mr. Crane, at the closing session, said:

> The success of the meeting is due to the tremendous interest aviation has aroused, and is universal not only among those actively engaged in this great work but also among the general public. Due to this interest, a wonderful future lies before the industry provided the interest is justified by the results obtained. This places a great responsibility on the engineers whose work it is not only to advance the art but to make clear what is and what is not possible so that there may be a minimum of disappointment.
>
> The Society will try to do its part in promoting the good work by continuing to act as the forum for aeronautical-engineering discussion. It is confidently hoped that the Aeronautic Meeting in 1928 will be even more interesting than the present one, because at that time it will be possible to present actual operating results of a number of different commercial airlines that started operations on a large scale last summer.
>
> I do not wish to close without paying a tribute to all branches of our Government for the interest they have shown and the constructive work they have done in advancing the possibilities of aviation. From President Coolidge down through all the executive departments, the industry has had sympathetic hearing and support. Private operation of these Air Mail lines will constitute the really first great test of commercial aviation in the world.
>
> With the encouragement and support of the Government and with the very able men who are interested in aviation, no doubt whatever exists of its future in this Country. Remarkable achievements have already been made and it has come into its own faster in the 10 years since the war than anyone had the right to expect. With this history back of it, its future looks wonderful.

PRE-MEETING LUNCHEON

Speakers at Tuesday's sessions and members of the Aeronautic Meeting Committee met at a preliminary luncheon in the Waldorf-Astoria at noon on the 18th to become better acquainted and to discuss final arrangements for the day's sessions. Members of the Committee present were Hon. Edward P. Warner, assistant secretary of the navy for aeronautics, and Chairman of the Committee; E. T. Jones, of the Wright Aeronautical Corporation, and vice-president of the Society, representing aviation engineering; W. L. LePage, with the Pitcairn aircraft interests; William B. Stout, of the Ford Motor Co., and John A. C. Warner, of the Studebaker Corporation of America. Paul G. Zimmermann, vice-president of the Society representing marine engineering, also represented the Society officially.

Those in attendance who were to speak at the meeting were, in addition to Mr. Stout, Prof. C. H. Chatfield, of the Massachusetts Institute of Technology; Charles B. Hall, of the Hall Aluminum Aeronautical Corporation; J. A. Roché, of the Army Air Corps; Igor I. Sikorsky, of the Sikorsky Aero En-

gineering Corporation; and E. W. Stedman, of the Royal Canadian Air Force.

The gathering was honored by the attendance, as special guests, of Edward F. Schlee and William S. Brock, who, upon their arrival, were acclaimed by a rising welcome and applause, in recognition of their world-famous flight from Detroit across the Atlantic to England, the Continent, India, China, and Japan in their attempt to fly around the world in less than 28 days.

Other guests were Richard I. Blythe, Harry Bruno and A. L. Greene of Bruno & Blythe; F. L. Curtis, of the *New York Sun;* Bruce Gould, of the *New York Evening Post;* Lieut. C. B. Harper, U. S. N.; James Larwood, of the *Evening Journal.*

METAL CONSTRUCTION WINS APPROVAL

Methods of Building All-Metal Planes Revealed—Corrosion Prevention Discussed

With Hon. Edward P. Warner, assistant secretary of the navy for aeronautics, at the controls, the Aeronautic Meeting took the air with a high rate of climb Tuesday afternoon, Oct. 18, at the roof garden of the Waldorf-Astoria Hotel in New York City. As chairman of the committee that arranged for the meeting, Secretary Warner said that whatever may be done in building and operating airplanes, the burden of progress is upon the engineer, and through the mutual helpfulness and free exchange of information that have always exemplified the spirit of the Society this burden can be carried most easily.

A tribute was paid to the memory of Charles M. Manly by Secretary Warner in words, by the whole company standing in silence for a short time, and by resolutions drawn up by a committee appointed by the Chair on the motion of J. A. C. Warner. The committee consisted of J. A. C. Warner, W. Laurence LePage and Secretary Warner.

Prof. Alexander Klemin was called upon to preside through the technical session, the first part of which was comprised of a symposium upon metal airplane construction. He immediately called upon W. B. Stout, of the Stout Metal Airplane division of the Ford Motor Co., to present a paper on Studies in Metal Construction.

Psychology was named by Mr. Stout as furnishing one of the important reasons for building airplanes of metal. Most men have more confidence in a metal airplane than in one having cloth and vibrating wires in sight, even though the engineering of the latter is good. As an extreme illustration of this prejudice, Commander E. W. Stedman, of the Royal Canadian Air Force, was quoted as telling of Indians in northern Canada who were quite willing to fly anywhere in airplanes until after they had been asked to help clear up the wreck of an airplane in the woods. When they found that the wings and the engine were hollow, the discovery made them nervous about flying.

Advantages of Duralumin Forms

The Stout airplanes are built from sheet duralumin in forms that can be produced by the machinery used in the ordinary metal-working shop. Forms like these can be made with very little investment for tools and can be repaired with equipment that is available in any medium-sized town. At the same time, this construction is adaptable to economical production in quantities. Sections are built up from sheet metal of different gages, and the design is checked by testing for column loads, since tension loads are not so large a problem. Steel might be used for tension stresses but for the difference between the expansion coefficients of steel and aluminum which would cause variation in the structure with a change of temperature. Fluttering is prevented in the monoplane wings by making the sheathing of corrugated metal in a form that offers rigidity. By using the sheathing in this way, the skin surface is secured with practically no weight added to the structural members. Veneer sheathing can be used to support tension but has very little strength in compression.

One of the important points in favor of metal is the uniform strength, whereas the strength of wood cannot be determined accurately, continued Mr. Stout. Another point is that a metal structure will be repaired with metal the same as the original, whereas wooden structures often are repaired with inferior material.

Mr. Stout passed around a number of sections showing structural details of his planes. One of the most interesting of these was a piece of a spar built up from a U-shaped section into which is fitted a lighter channel section, with the free edges of the two sections flush with each other. Two rows of rivets with all their heads exposed join these two sections into a D-shaped tube that is claimed to have advantages over a drawn tube because it will not give way without warning and because both surfaces of the sheet metal can be polished before forming, thus guarding against corrosion.

Charles Ward Hall, in his paper on Studies in Metal Construction, said that the comparative value of two airplanes of similar size, power, speed and other flying characteristics is measured by the useful load that each can carry. Difference in weight of the structural frame-work, therefore, affects the useful load and, with metal construction, light weight can be secured with the least cost.

Pressed Construction of a Flying Boat

Lantern slides showed the floor frames and keel of a flying-boat hull of Warren-truss form, blanked and pressed in dies, having the chords formed to an angle section and the webs formed approximately to a parabolic section. The floor frames are assembled to the keel with rivets and gussets, the rivets being so located as to be readily accessible and subjected only to shear. Necessary variations in the frames for different sections of the hull are made by interchangeable ends for the dies. The only labor involved in making a frame of this design is depressing the treadle of a punch press twice.

Other examples of pressed rib-work are ailerons weighing 2.6 lb. each, fins, rudders, stabilizers and elevators. Ribs of the tail surface also are made of different lengths from a single set of dies having a number of interchangeable parts.

Another slide showed the metal framework of a Navy pursuit plane said to weigh 167 lb., whereas a corresponding wooden frame weighed 361 lb. One of the wings illustrated was included in the Navy exhibit at the Sesquicentennial Exposition in Philadelphia. This was reported to be in good condition after 6 years' service, showing that lightweight metal airplane-structures are not necessarily sensitive to corrosion.

Sheet metal is made into flanged tubing and bulb angles by drawing the metal through dies. These forms were developed about 9 years ago and are useful for ribbed chords, seat backs, reinforcements and other structural elements. The flanges provide for easy attachment of other members. In some cases greater lightness can be secured with built-up construction than with pressed structural forms.

The third paper presented was on Selection of Materials for Aircraft Structures by J. A. Roché, senior aeronautical engineer of the materiel division, Air Corps, Wright Field, who said that it is important to know what increment of weight can be added profitably to gain a certain reduction in air resistance or a certain gain in horsepower.

Spruce, aluminum alloy, chromium-molybdenum steel, and heat-treated chromium-molybdenum steel were compared in tables as to their specific gravity and strength. One table gave the relative weight, depth and deflection of beams of equal strength made from these materials. This table is made on the basis of sections most efficient for each material. In case the beam height is limited, these proportions will not apply and the problem must be worked out with each different material, using a constant depth. Parts exposed to air-flow must be compared also with regard to both parasite drag and induced drag as affected by members made from heavier materials for the sake of a reduction in parasite drag.

Differential formulas and derivative values for various types of plane, and conclusions as to suitable materials under different circumstances, are given in the paper, which is printed in full in this issue of THE JOURNAL.

METAL SAVES WEIGHT IN NAVY PLANES

In the absence of Commander R. D. Weyerbacher, Construction Corps, U. S. N., manager of the Naval Aircraft Factory, Philadelphia, his paper on Metal Construction of Aircraft was read by Lieut. C. B. Harper, U. S. N., chief engineer of the Naval Aircraft Factory. This paper also is printed in this issue of THE JOURNAL and is illustrated with a number of photographs showing details and methods of construction used in a number of the Navy airplanes.

Swelling, warping, decay and insects are listed by Commander Weyerbacher among the ills of wood, and metal is said to be workable by pressing, rolling, drawing, extruding, forging and casting in addition to the methods applicable to wood and is better adapted to making joints. Ordinarily a saving of about 25 per cent can be made by changing from wood to metal construction, provided the design is made to take advantage of the qualities of metal, and a saving of 50 per cent is sometimes possible with extreme refinement in design.

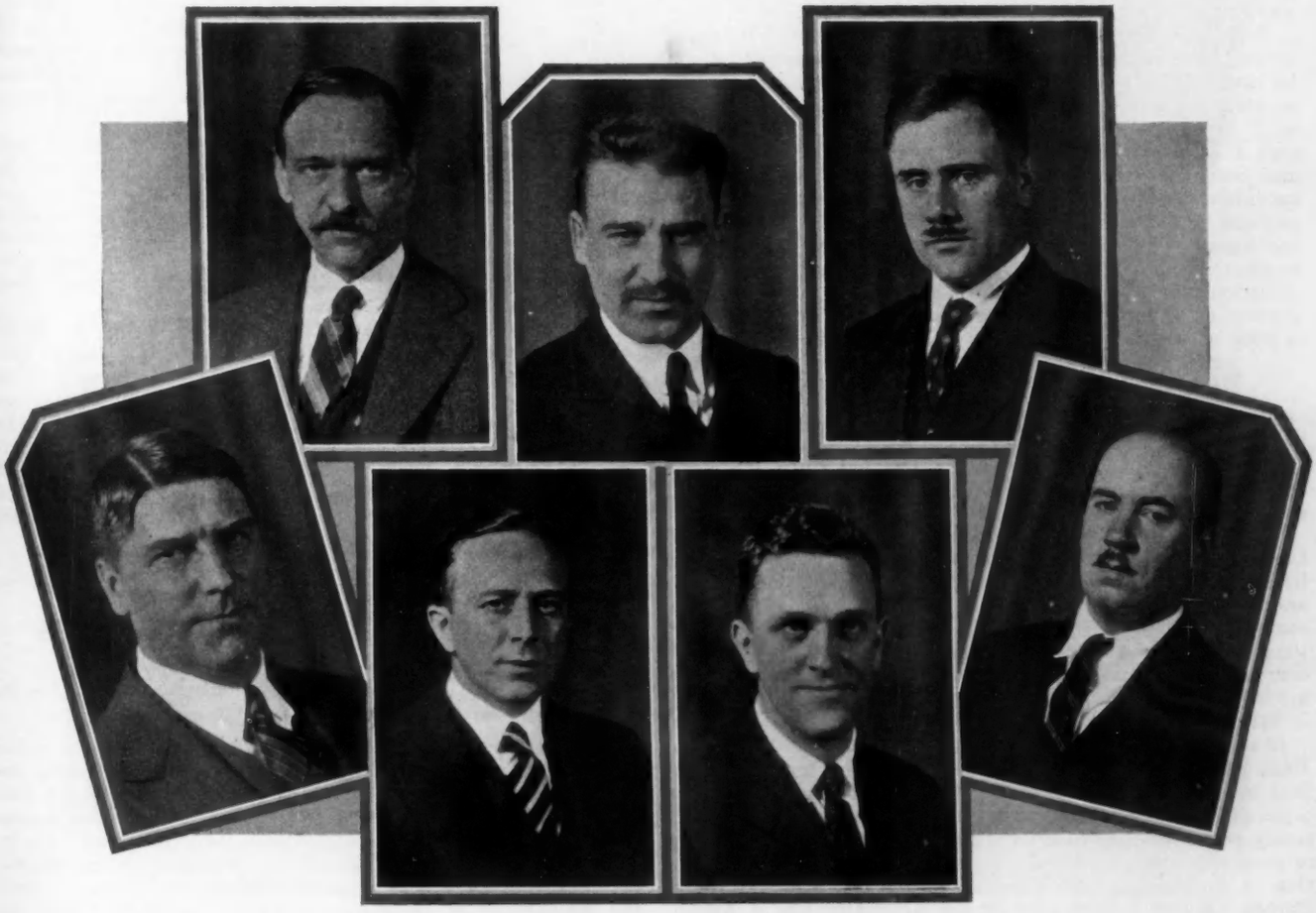
Much emphasis is laid in the paper on the importance of providing and maintaining a protective coating on all interior and faying surfaces for protection against corrosion.

CRAFT ASSEMBLED QUICKLY FROM STANDARDIZED PARTS

The symposium on metal construction was closed with a paper by I. I. Sikorsky, of the Sikorsky Aero Engineering Corporation, who said that inexpensive methods of construction and the psychological factor influenced him as well as Mr. Stout in adopting metal construction. Most of the airplanes built by his company are made to order, so the company standardizes methods of construction rather than complete planes. Quick delivery is usually desired and airplanes can be assembled in which standardized parts are adapted to the particular requirements.

Sikorsky wings formerly used ribs built up from channels. Pressed ribs are now used, with a little sacrifice in weight and a gain in simplicity and maintenance. Comparatively heavy sections are used to guard against the effects of corrosion.

Tubular construction in the fuselage, as formerly used, was lighter than the present angle and T-section construction. The tubes themselves are much lighter than the angles, but part of this advantage is lost in extra weight for the connections. Also, angles present a much simpler problem



SPEAKERS AND DISCUSSERS AT THE OPENING SESSION

In the Upper Row from Left to Right Are Charles W. Hall; Lieut. C. B. Harper, U. S. N., Who Represented Commander Weyerbacher; and J. A. Roché, Who Presented Papers on Developments in Metal Construction of Airplanes. W. B. Stout Also Presented a Paper on This Subject. Alexander Klemin Acted as Chairman. In the Bottom Row, from Left to Right, Are Starr, Truscott, C. F. Nagle and W. G. Brown, Who Took an Active Part in the Interesting Discussion That Followed the Papers; and I. I. Sikorsky, Who Also Spoke on Metal Construction

when additional equipment is to be mounted, and inspection of joints is more certain, as they contain no hidden bushings.

Mr. Sikorsky reported an experience to prove the greater safety of a metal airplane. Flying a heavily loaded 11,000-lb. craft, he was seeking a night landing at Roosevelt Field on Long Island. As the field was unlighted, he almost passed it before starting to land. The wings struck the tops of some trees in coming down, but the plane landed safely. Examination the next morning showed that the tops of several trees were broken and the leading edge of a wing was broken away entirely. The spar was considerably bent but it remained in place and made possible the safe landing. The speaker said he believes that a wooden spar would have broken, with disastrous results.

In conclusion, Mr. Sikorsky asserted that it is possible to build 100, 200, or even 500-passenger airplanes and that demands are now being made for flying boats and airplanes that will carry from 30 to 50 passengers. He does not consider the time ripe for the larger planes, but when they do come they must be made of metal.

Should Design for Easy Dismantling

Discussion of the symposium was on details of metal construction rather than any comparison with wooden structures. In reply to a question about the possibility of securing an aluminum alloy that can be welded, Mr. Stout and C. F. Nagle, of the Aluminum Co. of America, stated that the heat of welding returns an alloy to the condition of cast aluminum. Although a good weld can be made, the resulting strength at the border of the weld is reduced. The difficulty of inspecting a weld also counts against it and the riveted joint has an advantage because it will not fail without warning.

Secretary Warner remarked that a number of manufacturers have changed from wood to metal construction but he could not recall one who had adopted metal construction as standard and then changed to wood. It is desirable, he said, to design a metal structure for easy dismantling so that a damaged unit can be sent to the factory for repairs and reassembled in the field. A new technique of ground operation may be required because the units with light metal sections will not stand the rough handling that has been customary with wooden sections. Secretary Warner also emphasized the military advantage of developing metal construction, since metal is so much better adapted to the production of quantities of aircraft such as would be required in case of war.

Various Methods of Preventing Corrosion

A móst interesting portion of the discussion was on the subject of corrosion. The anodic process was mentioned by G. Betancourt, of the Aircraft Development Corporation, as satisfactory for duralumin, but expensive. In the future, new alloys may solve the problem.

The practice of the Loening Aeronautical Engineering Corporation for the prevention of corrosion was explained by B. C. Boulton, who said that the ribs are first given the anodic treatment and then finished with iron oxide and three coats of aluminum enamel. The metal is only 0.014 in. thick and he considers that thin metal actually does not corrode more rapidly than thicker metal, although a given amount of corrosion makes a larger percentage of difference in strength.

If metal is not wet it will not corrode, according to Mr. Hall, who said that lanolin adheres to a surface that has been given an anodic treatment, causing it to shed water like a sea bird. The experience of years has shown that a hard, sticky grease applied so lightly that it is scarcely perceptible is very effective in preventing corrosion. The main objection is that people are afraid that grease will soil their clothes. A new development by the Aluminum Co. of America is produced by giving to an alloy ingot a thin coating of aluminum that is 99.85 to 99.90 per cent pure. This coating remains on the alloy as it is worked into its final form and is effective against electrolytic action.

Mr. Stout confirmed the statement that oiled metal will not corrode, adding that polishing is an additional precaution and that a certain amount of oil remains from the rolling and polishing process. The Stout airplanes are given no protective coating but it is customary to wash them frequently, particularly to wash off any mud promptly. They have been operated but little on salt water but one of them was flying from Miami and Tampa, Fla., for 1½ years, after which careful examination was said to disclose no sign of corrosion.

Care of the polished metal surfaces of the Stout airplanes is an important factor of their corrosion resistance according to Mr. Nagle. He believes that airplanes ordinarily are used for months without washing. Under such conditions, even polished aluminum will corrode if unprotected, particularly in the joints where salt water can find a place to lodge.

Paint will not adhere to metal that is not scrupulously clean. The first requirement is a good cleansing medium to completely remove oil and grease. It is also important to paint the parts before assembly, as otherwise it is impossible to get paint into the joints. Corrosion is relatively easy to prevent on the wings except that water sometimes is trapped in the trailing edge. Extra coats of paint at this point would help.

Mr. Nagle also called attention to danger from failure to remove blistered paint completely after a repair job. In reply to a question about chromium-plating as a corrosion preventive for aluminum alloys, Mr. Nagle said that there is a possibility of electrolytic action between aluminum and any plating metal and that chromium would be the worst of all in that respect.

It was necessary to terminate forcibly the discussion on metal construction to leave time for presentation of the paper on Standardization Tests in the Wind-Tunnel, by E. N. Fales, who has been connected with the wind-tunnel work at McCook Field. As Mr. Fales is now in Iowa on account of his health, Mr. Roché presented his paper, which is printed in full in this issue of THE JOURNAL.

One-quarter of the 100 wind-tunnels that have been built are said to be located in the United States. They are the source of most of our knowledge of the dynamics of the air, but are very expensive to build and to operate. The paper deals with the discrepancies in results obtained in different tunnels, with the reasons and remedies for these, and with questions of scale effect and of velocities at which tests are desirable.

In discussing the paper, Mr. LePage spoke of the desirability of research with small flying models of larger airplanes, mentioning the DeHaviland Tiger Moth with 19-ft. wing-span and a speed of about 170 or 180 m.p.h. from an engine developing possibly 120 hp. Chairman Warner, who had resumed the chair, recalled that one of the large commercial airplanes now in use in Europe has an unusual form that was first tried in a model of one-third size with 40 hp. instead of 900 hp. The success of the small model led to building the 10-passenger airplane.

PLANE TYPES AND AIRWORTHINESS

Monoplane or Biplane, Single or Multi-Engine Craft, and Federal Control Discussed

Vigorously presented differences of opinion over the relative merits of monoplanes and biplanes did not develop as anticipated at Tuesday night's session, which toward the end became a debate of the advantages and disadvantages of the high-wing and low-wing types of monoplane. Similarly, the discussion on the subject of single versus multi-engine planes developed as great differences of opinion over the desirability of three-engine versus two-engine craft as over the single-engine versus the multi-engine plane. On both subjects the discussers seemed to be in agreement that each type has its own field and that, as William B. Stout said, "the wise designer will select that type which best suits his purpose." There was little difference

MEMBERS RESPONSIBLE FOR THE 1927 AERONAUTIC MEETING

Hon. Edward P. Warner (Center), Chairman of the Aeronautic Meeting Committee, and the Members of the Committee, William B. Stout (Upper Left), E. T. Jones (Upper Center), H. M. Crane (Upper Right), W. Laurence LePage (Left Center), Alexander Klemin (Right Center), Lieut. E. E. Aldrin, U. S. A. (Lower Left), John A. C. Warner (Lower Middle), and L. D. Seymour (Lower Right). Secretary Warner Also Discussed the Application of Commercial Aircraft in the Naval Service at the Wednesday Session, and Mr. Stout Discussed Metal Construction at the Opening Session. H. M. Crane and Alexander Klemin Presided at Two of the Sessions

of views regarding the desirability of a reasonable amount of governmental control of aircraft. Nearly 250 attended the session, over which the Hon. Edward P. Warner presided.

Chairman Warner, in his opening remarks, reverted to the time not so long ago when no regulation of transportation or of commerce was needed owing to the simple organization of society, which left to the small groups of individuals, partnerships and companies offering transportation service the judgment of the proper value and safety of that service.

Governmental Control to Continue Indefinitely

The chairman did not agree with the suggestion sometimes made that regulation of aerial transport will be temporary and in time aircraft will be made safe by airplane manufacturers and air-transport companies will regulate themselves; but, reasoning by analogy and experience in the motor-vehicle field, he expressed the thought that the individual airplane will remain the subject of regulation for an indefinite period.

Within the last 2 or 3 years, after the motor-vehicle had been developed to a high state and had come to number tens of millions on the road, government has recognized its responsibility to supervise the individual vehicle and make sure that its brakes, lights, signaling devices and other equipment are in satisfactory condition.

Fears entertained by some prior to the enactment of the Air Commerce Act that Federal control of aviation would be detrimental to aeronautic progress have not been realized, and nearly everyone is now well satisfied of the fact, as the law is being administered, and it is hoped always will be administered, in a reasonable way with the sole object of assuring the public safety and thereby giving reasons for increased public confidence in aviation.

Referring to the first speaker on the program, Commander E. W. Stedman, supervisor of operations of the Royal Canadian Air Force, Chairman Warner said that the Dominion anticipated the United States in assuming governmental control of aviation and for that reason Commander Stedman's views with regard to the assuring of airworthiness of airplanes were thought by the Aeronautic Meeting Committee to be especially worth presenting to an audience of aeronautical engineers in this Country.

Problems in Control of Airworthiness

Commander Stedman's paper, which was then presented, is printed in full in subsequent pages in this issue of The Journal. In it, the author strongly urges designers not to design aircraft barely to meet the minimum requirements established by the Government, but to design for greater strength so that it shall not be possible for airplanes to be broken in the air.

The speaker invited discussion of the question whether it is possible to hope that in the future the licensing of aircraft can be governed by a single enactment requiring that all aircraft and personnel engaged in civil aviation, including the passengers carried, shall be covered by insurance, pointing out that thereby the licensing by a government department could be dispensed with, as the insurance companies would check the strength of aircraft and make periodic inspections during service.

On this subject of control of airworthiness, Clarence M. Young, of the Department of Commerce, presented the second paper. This also is printed in this issue of The Journal and points out the many problems of a technical nature that confront the aeronautic bureau of the department in deciding how far to go and in what ways to supervise aircraft construction and operation. One statement in particular that tends to remove fears entertained by some in the industry is that the Department of Commerce has no desire to become paternalistic and to limit or inhibit design, or to inspect all materials of construction. Rather, the department feels that a manufacturer should set his own standards and see that they are maintained. Much has been accomplished in the few months of active operation of the aeronautic bureau of the Department, and there is reason to hope, said Mr. Young, that the near future will see definite progress in bringing about a combination of four elements that are essential in the successful operation of commercial air transportation; that is, airworthy aircraft piloted and maintained by a competent personnel and operated over specially equipped airways in conformity with standard air-traffic rules.

Monoplane and Biplane Types Compared

To secure the views of a disinterested observer regarding the relative advantages of the monoplane and biplane types of construction, the Aeronautic Meeting Committee, explained Chairman Warner, had cabled to Prof. C. H. Chatfield, of the Massachusetts Institute of Technology, who was last summer making investigations of aviation in Europe, asking him to prepare a paper on this subject for the meeting.

Professor Chatfield in his paper, which he then presented, made comparisons between the true monoplane and biplane types, disregarding intermediate types. He discussed the characteristics of each under the general headings of structure, aerodynamics and performance. The structure of a biplane is the more efficient, he said, and it is therefore to be expected that in any ordinary case of wings of equal size, of the same general type of construction and designed to the same load factors, the biplane wing-structure will be the lighter. In biplanes, the complete wing cellule weighs normally from 1¼ to 1¾ lb. per sq. ft., while in monoplanes the weight of the wings and any bracing commonly ranges between 1⅝ and 2½ lb. per sq. ft. Also, the biplane structure is more rigid than the monoplane structure. The monoplane, however, seems to lend itself better than the biplane to types of construction that are desirable from other points of view than that of structural efficiency, as, for instance, to metal construction. In the biplane the load on the wing spars may be so low that a metal spar designed only for the load would be deficient in local strength and would be difficult to manufacture. If the same airfoil is used in both types, the advantage undoubtedly will be with the monoplane because of the reduced parasitic resistance and elimination of interference between the wings.

Relations which the speaker gave of the aerodynamic characteristics of three well-known wings, the U.S.A.-35, a pure cantilever monoplane; the Clark-Y semi-cantilever monoplane for single-bay biplanes; and the R.A.F.-15 thin wing for biplanes only, provide a reasonable explanation, said Professor Chatfield, for the popularity of the semi-cantilever monoplane and for the adoption of the long-bay airplane, in which the parasite resistance is decreased and there is comparatively little increase in wing drag. The total drag of the monoplane is about 5 per cent less than that of the better biplane.

To be the equal of the biplane in stability and control, the monoplane must have larger tail surfaces. On the other hand, the monoplane seems to be free from the dangerous flat spin to which the biplane is subject. In addition to direct aerodynamic superiority, the monoplane wing has the advantage that its greater thickness makes possible locating within it such objects as the fuel tank, which in a biplane might have to be placed in the wind, at the cost of increased parasite resistance.

Each Type Holds Performance Records

As for performance, the records for range and endurance are at present held by the monoplane, whereas the altitude record and several of the combination speed-and-load records are held by the biplane. Results of the recent Schneider Cup race in Italy indicate that, in the matter of pure high speed, there is not much choice between the two types.

The biplane will ordinarily have a substantial advantage in the matter of size, and this consideration is paramount for airplanes that must be stowed between the decks of an airplane carrier or where space in a hangar is limited. However, a monoplane having folding wings that do not extend beyond the tail surfaces is on a par with the biplane.

Visibility is better from a monoplane than from a biplane, except in the case of the low-wing monoplane. There does not seem to be much choice between the two types in the

matter of safety. Two or more engines usually can be supported in the biplane with less additional bracing than on the monoplane. It is to be expected that, in similar types of construction, the monoplane will have superiority in the matter of initial cost and cost of maintenance, as it is of simpler construction and has fewer parts and fittings, but, as between the metal monoplane and the wood biplane, the latter probably is cheaper.

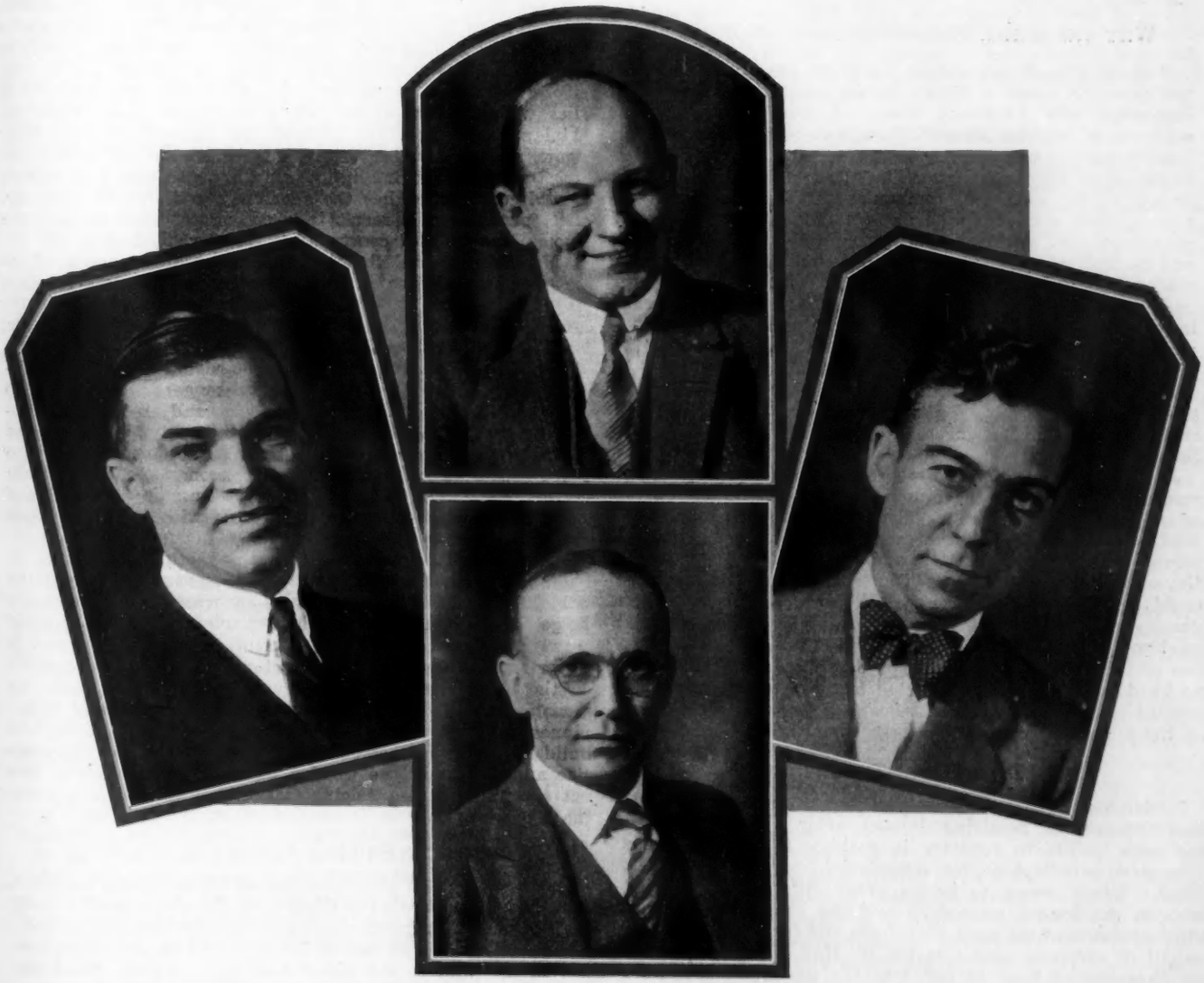
Anthony H. G. Fokker, of the Atlantic Aircraft Corporation, who has built airplanes all the way from one to five engines, believes that the multi-engine type is preferable to the twin-engine type. In his paper on this subject he classified airplanes of the multi-engine type into those capable of continuing flight with full normal load if one or more engines ceases functioning and those not able to continue flight. In the latter class, the actual risk of a forced landing is nullified by the number of powerplants used and, therefore, liability decreases with the number of engines.

If a twin-engine plane has been in service for some time, its efficiency is decreased and it does not have sufficient reserve of power to run on one engine, without overheating or overstraining it, for a long enough time to be reasonably sure of reaching a safe landing place. To assure safety in event of the stalling of one engine, the pay-load would have to be reduced to such an extent that the craft could not be operated economically. The conditions differ in military use, where the excess load can be dropped if necessary to continue on one engine, but in commercial work it is not feasible to drop the passengers and their luggage. Mr. Fokker said that the multi-engine principle positively must be considered as insurance against a forced landing due to failure of one powerplant; this insurance cannot be obtained, however, for nothing, as it costs more in fuel consumption and head resistance and, therefore, intrinsically a single-engine ship of corresponding design and power will have a longer range.

In simplicity, in efficiency, initial cost and operating economy, the advantages are all on the side of the single-engined plane, and its reliability undoubtedly is great; nevertheless, any failure due to engine trouble may be very deplorable. If multi-engine ships are selected to obtain the highest degree of safety, the minimum number of engines should be three, but Mr. Fokker does not believe, he said, that it will be worthwhile to adopt this principle in the smaller and relatively cheaper aircraft.

Inspection and Regulation Discussed

Integrity of the manufacturer is the ultimate solution of the problem of airworthiness, in the opinion of C. H. Biddlecombe, aeronautic transportation engineer, New York City, who said that he had found in England that it was extraor-



Speakers Who Discussed Airplane Design

A. H. G. Fokker (Upper Center), Who Discussed Single Versus Multi-Engine Planes; Commander E. W. Stedman (Left), and C. M. Young (Right), Who Discussed Control of Airworthiness, and Prof. C. H. Chatfield (Lower Center), Who Discussed the Relative Advantages and Disadvantages of Monoplanes and Biplanes

dinarily difficult to try to enforce cut and dried regulations regarding safety factors, airworthiness, and materials. It was impossible to watch every manufacturer and his sources of supply of material, to test his materials, watch his workmen and keep a paternal eye upon him. Such a system would be costly and also hindering. Regulation, he said, will be interpreted in common-sense ways, as it is now, and we shall get good airplanes through the honesty of the manufacturer; and those builders who turn out good aircraft will capture the whole market.

Mr. Fokker expressed satisfaction that builders in the United States have seldom been hampered by regulations such as had been inherited in Europe from the World War and have had disastrous effects. All the "gypsy" fliers and "Jennies" will disappear, he said, and the reputable builders and operators who maintain uptodate aircraft and effective inspection will build up a reputation and remain in business. In rebuttal, Commander Stedman pointed out that, unfortunately, at present some constructors are meeting only scantily the minimum governmental requirements, which are not sufficient in themselves. The inspection that will be needed is of the builder who is less interested in producing a good airplane than is the department in having him do so. Another point is that the manufacturer has no control over his product after it goes into the hands of the purchaser; that is the important place for the inspection system to function.

Why Insurance Companies Make Inspections

Taking over of inspection work by the insurance companies would place a heavy burden on the applicants for insurance, said Archibald Black, of New York, who has made most of the aircraft insurance inspections in the eastern part of the Country in the last few years. The Department of Commerce has relieved the companies of much worry, as the insurance companies assume that the structure is right and confine their own inspection to operating conditions, such as flying-fields, terrain over which the craft will fly, and the care with which they are maintained. Three reasons why inspection by insurance companies is never likely to be eliminated are that the companies want as recent information as possible on the condition of the craft, an appraisal of value is often made a part of inspection, and the measure of inspection is taken in dollars rather than in safety. Mr. Black suggested that stress be placed upon the necessity of keeping log-book records complete and urged that penalties for falsification of log-books be rigidly enforced.

J. Otto Scherer, of the Junkers Corporation of America, voiced the view that the only true criterion of the factor of safety is the sand load a plane can stand after it has been used, and suggested that occasional tests of machines in service be made by inverting and sand-loading them to the Government requirements. To require that no airplane could be broken in the air would, however, place a high penalty on the efficient machine. An efficient commercial machine of low horsepower per pound of weight can acquire two or three times its normal speed in a dive and, if pulled up hard enough, can be subjected to the same stresses as a pursuit plane. The solution seems to be a more rigid check on the pilots and how they behave when flying.

All Types Have Their Place

Initial cost, relative facility and cost of maintenance, and ease and cost of repairing damage after a forced landing are some points to consider in making a choice between monoplane and biplane for commercial operation, said Mr. Black. There seems to be no great difference in weight between the braced monoplane and the single-bay biplane-wing structure of the same plan form and for the same gross weight of airplane, said Charles W. Hall, who thinks that an allowance of 8 or 10 per cent for the bay monoplane-wing will cover it. Igor Sikorsky, of the Sikorsky Aero Engineering Corporation, stated that last year his factory built some biplane wings and this year built some monoplane wings of approximately the same area and of similar construction, all for existing types of airplane, and tested them on several craft. Both types seemed to give the same results and no material difference could be found.

The problem of design, as in any other airplane work, depends upon what the designer is setting out to solve, asserted Mr. Stout. Possibility of the use of metal construction largely governed his company's selection of the monoplane. Since the war it has been learned how to use several materials for the skin of the thick wing, such as veneer or metal, so that the skin becomes part of the structure, giving it strength and rigidity. In commercial work the combination of load with speed is the objective to be sought, and lift is wanted. Profile drag of a section amounts to very little, and no reason exists why a thick wing should not be as efficient as a thin one, but the thicker it is made at the root the lighter the structure can be. With a tapered wing-section, good snappy aileron action is secured without induced drag from the vortex at the tip.

The high-wing monoplane is much less liable to damage from trucks backing up to the fuselage to load and unload cargo than the biplane or low-wing monoplane; and maintenance cost is severely affected by the location of the door with relation to the rest of the structure of the airplane.

High versus Low-Wing Monoplane

The airplane of the future must be a passenger ship, observed John C. Lee, of the Fairchild Airplane Corporation, and it is to be considered that the view of the landscape is best from a high-wing monoplane. The cleaner, simpler appearance of the monoplane when on the ground is also more attractive to passengers. Advantage in initial cost lies with the monoplane, which has fewer parts than the biplane and, therefore, reduces the amount of assembling work and the number of jigs required. We are now entering upon the beginning of quantity production in which metal construction has the advantage and this, thought Mr. Lee, probably will result in a strong tendency toward the monoplane type of construction for the small airplane.

Mr. Scherer said that he was rather an exponent of the low-wing monoplane of cantilever type as the wing weight is about 40 per cent of the total weight of the airplane, and with a low wing the center of gravity is much lower, so that when taxiing this type is safer against turning over.

Mr. Fokker said he thought that visibility from an airplane has very little influence on passengers who will go up in an airplane no matter how it looks, and are far more interested in getting a ride for $2.50 than for $5.00. Repairs on a low-wing monoplane, in case of an accident, usually are more expensive than on a high-wing monoplane, as with the latter, when it noses over, only the nose is damaged and the airplane turns over on its back without doing much damage to the wings.

He has built every type of airplane under the sun, he said, and has found that there are certain reasons for building a biplane or a triplane. In the war, when it was necessary to get great altitude and high maneuverability, the triplane was the most efficient. In pursuit work, the biplane is superior as it has a very high factor of safety and on account of the shorter wing-span is more maneuverable than the monoplane. Five years ago, when he began building monoplanes, he went to Adolph Rohrbach and offered to let him build the wings of metal if he could make them of the same size and weight as the wooden wings, but the contract was not accepted because Adolph Rohrbach could not guarantee the same weight.

Would Put Engines Inside the Fuselage

On the subject of the single versus the multi-engine plane, Mr. Fokker commented ironically on the practice of placing engines and other parts outside of the fuselage, saying that, if any constructor of racing boats placed his cylinders outside of the hull to get direct cooling, everyone would say that he knew nothing about engineering.

"There are many questions to solve," he said, "but the big monoplane wing will be the answer." If the engines are placed in the wings, he continued, with several engines

working through long shafts on one transmission and propeller, the designer will get into difficulties over the construction of gears, clutches and variable-pitch propellers. This is the reason why more progress is not made with the large monoplane wings, as the difficulty is not with the wing but with engine installation and all the problems connected therewith.

Two Engines Safer than One

Igor Sikorsky did not agree with Mr. Fokker that the twin-engine offers no greater security than the single-engine craft. He has built airplanes with two, three, four and five engines and said he agreed with Mr. Fokker that the single-engine plane is the most efficient type, and that with a full load, when it is necessary to run with one engine dead, three, four, or even five engines will be necessary. However, in localities where landing-fields are always available within 25 to 50 miles, it is entirely feasible to reach one with a twin-engine airplane if one engine stalls, as has been proved many times. But in a flight of from 500 to 800 miles over the sea, or several hundred miles over high mountains, two engines will not be sufficient. Every type of ship, however, has its own field of action and there is not the slightest doubt that all of them will remain, both for military and commercial work.

"One important advantage possessed by the twin-engine plane over the single-engine craft," asserted Mr. Black, "is that it has a greatly increased gliding range if one engine continues running." However, in any multi-engine ship, if the gasoline systems are coupled so that a break at any one point will shut down all the engines, it is no better than a single-engine plane. High cost of overhaul is a disadvantage with the multi-engine craft, as the cost of overhaul in an engine is governed by the number of cylinders.

Multi-Engine-Drive Units Available

Clarence Hanscom, consulting engineer of East Orange, N. J., said that he believes the future for the large commercial type lies in the multiple powerplant located in a central engine-room so that any one engine can be disconnected and put in running order again while in flight. E. T. Jones, of the Wright Aeronautical Corporation, stated that this type of construction is open to the basic difficulty that all of the powerplants are connected at a single point where failure will stop all of them at once, as in the event of a broken gear-tooth. Moreover, such a transmission adds weight and it is very doubtful whether the reduced head resistance will counterbalance this. He said that while at McCook Field, he supervised the design, construction and endurance test of a unit of this type which passed the 50-hr. test without any failure or forced stop; that this unit weighs less than ½ lb. per hp. and has been available to constructors for 3 years, but no one has seemed to care to design an airplane around it. Chairman Warner stated that about 10 or 12 years ago laboratory tests were made on such a powerplant but that it has received very little favorable notice.

AVIGATION PAPERS PRESENTED

Oversea Avigation and Instruments Are of Interest—Industry's Relation to War Told

General interest in the subject of oversea avigation was reflected in the Wednesday afternoon session at which W. L. LePage, of Pitcairn Aviation, Inc., acted as chairman. As Lieut. Albert Hegenberger, of Army Hawaiian-flight fame, and Bradley Jones were delayed in flying to the meeting from Wright Field, Dayton, their paper on Oversea Avigation was read by Victor E. Carbonara, of the Pioneer Instrument Co.

Drawing upon his own experience and that of other transoceanic fliers, Lieutenant Hegenberger told of the methods of avigation with the aid of dead-reckoning, astronomical observation and radio. The effect of fatigue is more important on the avigator than on the pilot because the work of the latter becomes partly subconscious, while that of the former depends on mental activity which cannot become subconscious.

Thorough preparation for the flight in other than physical equipment is very important. Before the successful flights of the ZR-3 over the Atlantic and of the Army seaplane to the Hawaiian Islands, the flights were made hundreds of times on weather maps. The contribution of the meteorologist is a most important factor. Climatology decides the choice of the route, while meteorology decides when the route may be flown and also where deviations should be made from it. Preparatory work includes not only studying many times the conditions on the weather map but also a large amount of precomputation. As action is so much more rapid in the air than in the water, the avigator must get the results of his observations within a much shorter time than is allowed to the ocean navigator. There is not time for the customary calculations.

To meet these conditions, the Army Air Corps has worked out a method of making in advance many of the computations that will be needed. This involves many times the amount of mathematical work that would be required for the actual observations taken, but this work is worthwhile because it can be done under favorable conditions and it saves time in the air. On the Hawaiian flight a master aperiodic compass was mounted on a non-magnetic tripod in the navigator's cockpit. For steering there were an induction compass and two magnetic-needle compasses. Mechanical failure interfered with the use of the induction compass. The two other compasses were of an experimental type with a very legible and steady card.

Drift Is Hard To Measure

Measuring drift is one of the great problems. One of the slides presented with the paper showed lines radiating from a point in the cockpit painted on the upper rear surfaces on the Army Hawaiian plane. Sighting a smoke bomb, or a lighted bomb at night, after it has been left a couple of miles astern will give an accurate measure of drift with the aid of such lines. Weather conditions on the Hawaiian flight interfered with this method of observation, however, and use was made of the conventional wire-vane drift-sight.

For use on an airplane a sextant must be light and compact. As the natural horizon is often indistinguishable, reliance must be placed on an artificial horizon provided by a bubble, which is a poor substitute. It is very difficult to obtain accurate readings under such conditions.

Radio is used in avigation by taking bearings on transmitting stations with goniometer loops on the aircraft, by securing bearings from nearby boats, and by means of the radio beacon. The last two of these methods seem to have met with the most success.

Full use should be made of dead-reckoning and of astronomical and radio avigation for any transoceanic flights attempted, until these methods are more completely developed and are assured freedom from outside influence, according to the Hegenberger and Jones paper, which will be presented in an early issue of The Journal.

Mr. Carbonara next presented his own paper on Instruments for Oversea Navigation, printed in this issue, in which he indicated the complexity of aircraft position-finding and described magnetic and earth-inductor compasses, speed and drift meters and octants for astronomical position-finding.

An octant is similar to a sextant, except that its arc is 45 deg. instead of 60 deg., and it is used for measuring the angular elevation of a celestial object above the eye of the observer. The natural horizon loses definition rapidly as the airplane rises and it is therefore necessary to use a bubble level, a simple pendulum or a gyroscopic pendulum as a substitute. It is also necessary to introduce a correction for the elevation of the eye above the horizon.

In the discussion on the foregoing papers William G. Fisk told of three types of aircraft transmitters developed by the Radio Corporation of America, with which organization he is connected: a 10-watt set for short flight-distances, an interme-

AUTHORS AT THE AVIGATION SESSION

Victor E. Carbonara (Left), Who Discussed Instruments for Oversea Navigation; Bradley Jones and Lieut. Albert Hegenberger, U. S. A., Whose Paper on Oversea Avigation Was Presented by Mr. Carbonara; and F. C. Hingsburg (Right), Who Discussed the Engineering of the Department of Commerce Airways

diate 75-watt size and a large set of 300 to 350-watt rating. These transmitters can be used either for telephone or telegraph transmission, the latter giving about twice the range of the former. The corporation also has designed a beacon-signal receiver, weighing about 10 lb., that can be installed in the cockpit of an airplane or in the fuselage with a control box near the pilot.

Radio beacons of 2-kw. size are being installed by the Department of Commerce at various fields and can be supplied to airports that do not wish to await the action of the department. Beacons are now installed at College Park, Md.; Bellefonte, Pa.; and at Hadley Field, New Brunswick, N. J.

METEOROLOGICAL COOPERATION RECOUNTED

Dr. James H. Kimball, Weather Bureau meteorologist in New York City, spoke of the difficulty encountered during the summer just passed because of the lack of a common language between the aviator, the engineer and the bureau. This situation should be improved. There must be a great amount of information in the minds of the various trans-ocean fliers that could be brought out at a conference.

The information given by the Weather Bureau to the various trans-atlantic flyers generally proved accurate, he said, particularly as to the barometer and the winds to be encountered. The condition that nearly caused disaster to the Byrd flight was an area of low pressure which appeared after he left the British Isles and was very unusual. British meteorologists cooperated at that time with those in America and the experience of one summer shows the need of international cooperation in making up the weather maps. The different units of measurement used in the various countries introduced difficulties.

The regular maps of the Weather Bureau are made from the observations from ships and transmitted by mail, so the information is 6 weeks old, said Dr. Kimball. Such maps are good for study but are useless for actual flying. Commander Noel Davis was the first of the fliers to ask assistance of the Weather Bureau this year, asserting that aircraft had as much right as ocean craft to the service. As the bureau had no funds for the purpose, he asked the Radio Corporation of America to collect the weather reports by radio. Without specific authority, the Weather Bureau has done what it could to keep the fliers out of danger when a general storm is in progress, but it has not been able to advise of squalls or local storms. Ruth Elder and George Haldeman were warned of the storm which they encountered 36 hr. after their start, but chose to take their chances with it. It had been reported for about a week and they were not willing to wait longer.

AIR-MAIL EVIDENCE INTRODUCED

The Air Mail was represented by Wesley Smith, superintendent of the eastern division of the National Air Transport, Inc., who said that the Weather Bureau sends information to the Air-Mail stations at Hadley Field and at Cleveland at 9 a. m. and 9 p. m., from which weather maps are made, giving necessary information for the next 24 or 36 hr. Additional information is secured from local stations of the airways division of the Department of Commerce along the line.

Except for trouble from ice, it is possible to fly through any weather with proper instruments, but it is not possible to land safely unless the pilot can see. Lloyd W. Bertaud and James DeW. Hill, formerly Air-Mail pilots, planned their ill-fated expedition to demonstrate this, said Mr. Smith. The only reason for delay was that they needed a 20-mile wind to help them rise because of their heavy load. Their disaster was due to engine failure.

The Air-Mail Service did some experimenting with the radio beacon, and Mr. Smith's organization plans to begin work with it soon. The great needs of the pilot in the way of flying aids were said by Mr. Smith to be: (*a*) something to keep him on his course and correct for drift as the radio beacon is supposed to do, (*b*) better conditions for landing through fog and (*c*) an altimeter that registers accurately the height above the ground immediately beneath, regardless of the starting point and the barometer reading.

HELP PLEDGED TO AVIATION INDUSTRY

Interest of the National Safety Council in aeronautics was reported by N. R. Palmer, who expressed gratification for the remarkable reduction in fatality rates of flying under careful supervision, resulting in the loss of only two lives in the Air-Mail Service in the last year of Government operation. The council has pledged its support to the airplane industry in any way possible, realizing that in any new industry the pioneer pays the price.

Called upon by the chairman, J. H. Hunt, president of the

Society, expressed appreciation for the work of the Aeronautic Meeting Committee in preparing for the meeting, voiced the tremendous interest of the Society in serving the aeronautical engineer in any way possible, and asked for suggestions as to any service that might be rendered.

Department of Commerce Airways Engineering

In presenting his paper on Department of Commerce National Airways Engineering, Frederick C. Hingsburg, chief engineer of the airway division of the department, said that the Air Commerce Act of 1926 provides for the erection, operation and maintenance of all necessary air-navigation facilities, except airports, along civil airways established by the Secretary of Commerce; for the encouragement of air navigation facilities; and for aircraft examination and rating. More than 4000 miles of National airways have now been lighted and the mileage will be nearly doubled next year, he said.

Facilities to be provided include intermediate landing-fields, lights for night flying, weather service and its communication and radio beacons. Beacon lights are placed approximately 10 miles apart and ground markers are provided at beacon sites for identification during the day. Supplementary lights flash the numbers of the beacons at night and figures serve by day. This paper will be found in full in subsequent pages of this issue of THE JOURNAL.

With reference to the development of passenger transportation by air, Chairman LePage said that the Air-Mail operators are not ready to carry passengers on their regular routes, as it would not be wise to institute regular air-passenger-service by night without further ground organization.

The 30-mile spacing for intermediate landing-fields was questioned by Archibald Black, who said that this would call for flying at an altitude of at least 8000 ft. He also questioned using a wind velocity of only 70 m.p.h. as a basis for designing beacon towers, as that velocity is frequently exceeded and bridges usually are designed for a 100-m.p.h. wind.

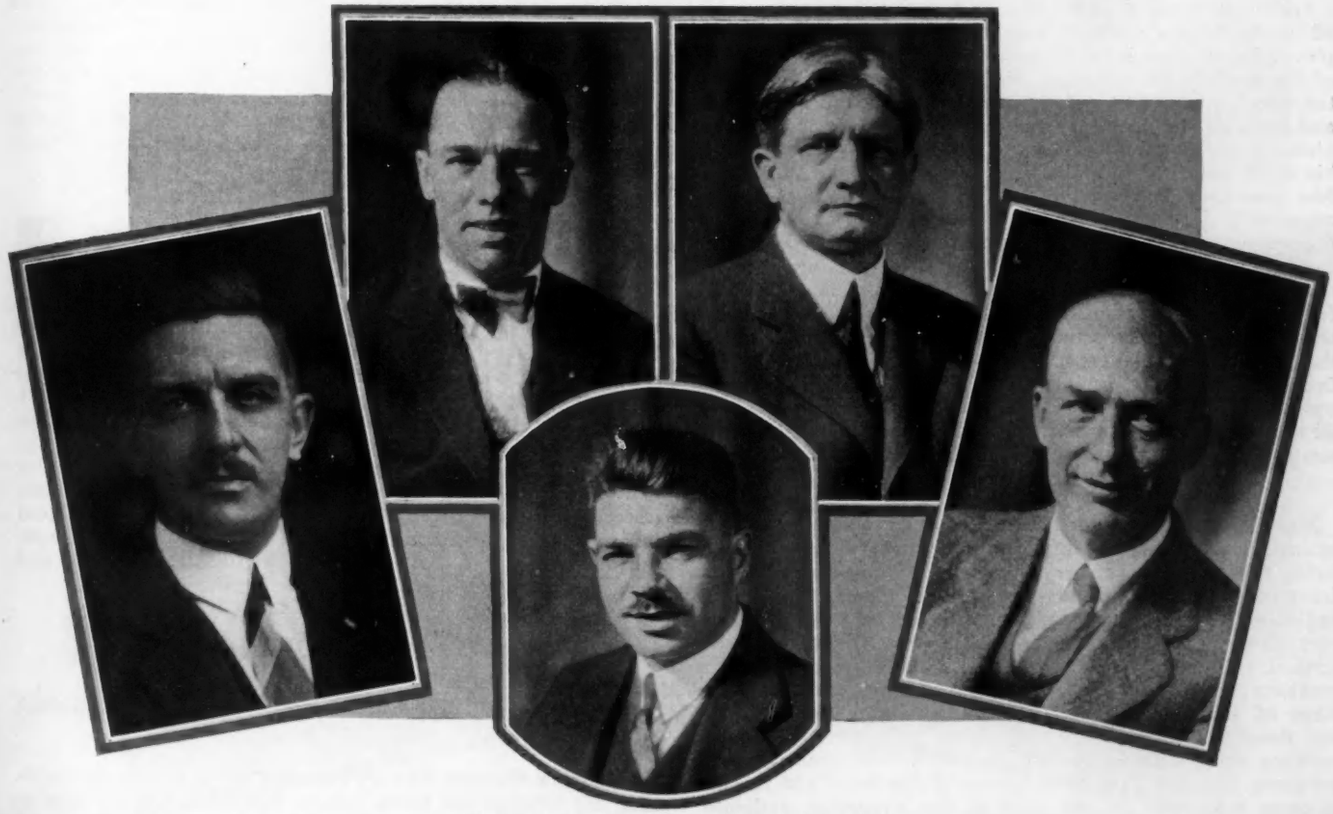
Mr. Hingsburg replied that the 30-mile spacing is based on the experience of the Air-Mail Service to provide for landings on account of the weather, which hampers air transport more than anything else. Mechanical failures are secondary and it is considered impossible to provide sufficient landing-fields to enable safe gliding to a landing from an altitude of from 300 to 500 ft. at any point along the course. Secretary Warner concurred in this statement. The beacon towers are bought in quantities at a cost of $106 each, and about 450 have been erected so far. There has been no failure of a tower based on the design described, according to Mr. Hingsburg.

Secretary Warner Presents Paper

The application of non-military aircraft to Naval purposes was next considered in the paper presented by Secretary Warner, also printed in this issue of THE JOURNAL, in which he said that there is no likelihood that airplanes used for commercial transportation ever will be drafted for military service except for the rapid transport of men and supplies. As a parallel, no attempt was made to rob the American railroads of their equipment in 1918. During a war it is necessary, rather, to expand the transportation facilities of the Country.

Airplanes for preliminary training service would undoubtedly be secured from manufacturers of such planes as could be adapted to the work with the least change in design, said the speaker. This would provide for rapid development of flying personnel, which is harder to secure than physical equipment. Other manufacturers would be asked to produce planes of military design, or such parts as they might be fitted to provide. In time of peace it is best to leave the industry unhampered to develop along commercial lines.

Commander E. W. Stedman, of the Royal Canadian Air Force, approved of this policy in regard to the design of commercial airplanes. All Canadian pilots are now required to be members of the Canadian Air Force, he said. The



DISCUSSERS AT THE AVIGATION SESSION

Wesley Smith (Center), National Air Transport Pilot; P. C. Ritchie (Left), of the General Electric Co.; E. P. Lott, Manager of Operations of the National Air Transport, Inc.; Dr. Charles Kimball, Meteorologist; and J. H. Geisse (Right), of the Naval Aircraft Factory

peace-time development of ground equipment will be of tremendous help in case of war.

R. W. A. Brewer, who was an inspector of mechanical transport supplies during the World War, recalled that British subvention of trucks for military service was not successful at that time. Because road conditions in America were more nearly like those encountered in war operation than were English road conditions, American-made vehicles proved more successful.

Opposition to any plan to muster all pilots into a reserve was expressed by Secretary Warner. Any gain immediately available in case of war would be more than offset by the psychological effect of any conscription in times of peace.

HADLEY AIRPORT SEEN IN ACTION

Thrills Provided by Night Arrival and Departure of Transcontinental Air Mail

Out of a sky obscured by lowering black clouds that overhung Hadley Airport, near New Brunswick, N. J., on the night of Oct. 19 and weeped a fine misty rain on the 75 or more members and guests of the Society who had come from New York City to witness the spectacle, an airplane glided smoothly and casually down to a safe landing on the wet field that shimmered in the glare of a floodlight, thus completing another successful Air-Mail flight from Boston to this airport.

The occasion was an inspection trip and evening session planned as a feature of the Aeronautic Meeting; and the spectators, ranged alongside one of the hangars to view this arrival and the subsequent take-off of another airplane carrying mail for Cleveland and the West, were thrilled by the nonchalance and the certainty exhibited by the pilots in controlling their craft when flight conditions are bad. A layman could be equally unconcerned and equally unconscious of imminent danger were he to take a stroll in a park on a bright May morning.

Opportunity was afforded also to witness the procedure of lighting the airport for the reception of an incoming airplane, its storage in a hangar, the transfer and placement of the mail in the outgoing craft, the try-out of its engine, the pilot's final tests and adjustments after taking his seat, and then all the details of the take-off. In this instance the pilot wasted no time on the ground after the start; he and his craft vanished into the blackness of the night almost in less time than is needed to write about it. It was a finale apparently innocent of any need for fearless courage and expert knowledge on the part of the pilot seated so comfortably on his parachute pack there in the snug cockpit, and one that also seemed devoid of any urgent necessity for special design and reliability of the craft itself; yet there lingered in the minds of the watchers the thought of the ever-present dangers the pilot and his machine were facing continuously during flight at night across the country and the mountains, because they realized how suddenly all the resources of the man and of his machine might be demanded at any moment by extraordinary conditions met.

Airways and Airport Lighting

Many uses of the motor-truck already have been discovered by members of the Society, but one hitherto largely neglected is its utilization as a high-powered movable rostrum from which to deliver addresses and read papers before an audience. Such usage was demonstrated in a Hadley Airport hangar following the Air-Mail spectacle already described. A motor-truck loaded with a chairman and two speakers was backed up within safe distance of the assemblage of standees inside the brilliantly lighted hangar, the end doors of which were left open, perhaps so that the rostrum, the chairman and the speakers could make a quick get-away into the wide open-spaces of Hadley Field in case of open hostilities on the part of the expectant audience. With safety first thus carefully arranged for, an introductory address by the chairman and two worthwhile papers by eminent authorities in their respective subjects were unloaded successfully upon the innocent bystanders. Partly because Hon. Edward P. Warner, assistant secretary of the Navy for aeronautics, was chairman, and also because all that he and the other speakers spilled off of the back end of the truck was welcome news to the listeners, no need developed for causing the movable rostrum and its cargo to vanish into the night as the Air-Mail pilot did; but the principle of using this form of rostrum seems sound and possibly is worthy of extended application.

Airway Lighting was the subject presented in the paper by Preston R. Bassett, of the Sperry Gyroscope Co., which was read in outline by C. D. Jobson, of that company. After reviewing briefly the development of airways, the author mentioned the three different types of beacon installed originally by the Post Office Department on the first complete night airway between Chicago and Cheyenne. These were respectively the 36-in. high-intensity projectors located every 200 miles and having a range of more than 100 miles, the 18-in. incandescent airway beacons located approximately every 20 miles and having a range of 20 to 30 miles and the small acetylene flashing beacons located at 3-mile intervals between the other beacons and having a range of 2 to 3 miles. On the later airways there are two types of 24-in. incandescent revolving beacons. The optical system comprises a 24-in. silvered glass parabolic mirror of 10-in. focal-length and a 1000-watt 115-volt incandescent lamp having a concentrated filament similar to that of the projection type of lamp; the average life of the lamp is 500 hr. and the intensity is about 2,000,000 cp.

Lamp changers, that is, automatic devices for bringing a second or spare lamp into the focal position of the mirror when the first lamp burns out, are used to increase still further the reliability of the beacons. Two types of lamp changer are used; one has thermostatic control and the other is controlled electrically. Beacons are now mounted on standard 51-ft. steel towers. The present standard rate of rotation of the beacon is 6 r.p.m. Many of the beacons are located in open country where it is difficult to obtain daily maintenance attendance; the beacons are therefore switched on in the evening and switched off in the morning either by an astronomical clock or a sun valve. Power is obtained either from the local electric-current supply or from a farm-lighting powerplant. Other types of beacon for special conditions were mentioned by the author and the lighting of intermediate landing-fields was described, inclusive of boundary lights, wind-cone illumination, obstruction lights and floodlights.

Airport Lighting-Practice

In his paper on Airport Lighting, H. E. Mahan, of the illuminating engineering laboratory of the General Electric Co., Schenectady, N. Y., outlined briefly the essential items and general practice in the lighting of airports for night operation. It was stated that the success of commercial aviation demands that operation continue throughout the hours of darkness and that artificial light provided during this period shall add no hazards which will interfere with the safe and practical conduct of the airport activities. The problem has been approached from the viewpoint of the engineer, the aviator being relied upon to contribute his experience in establishing the requirements and judging the effectiveness of the facilities provided. The paper included information regarding the beacons which indicate the location of the airport, the obstruction and approach lights and the methods of floodlighting the landing-field.

ENGINES AND AIRPORTS FEATURED

Supercharging, Engine Maintenance, and City-Planning for Airports Discussed

Following the introductory remarks of H. M. Crane, chairman, the first of the three papers scheduled for the session held Thursday afternoon, Oct. 20, was presented by Opie Chenoweth, carbureter development engineer for the Army Air Corps, Wright Field. It was entitled Supercharged

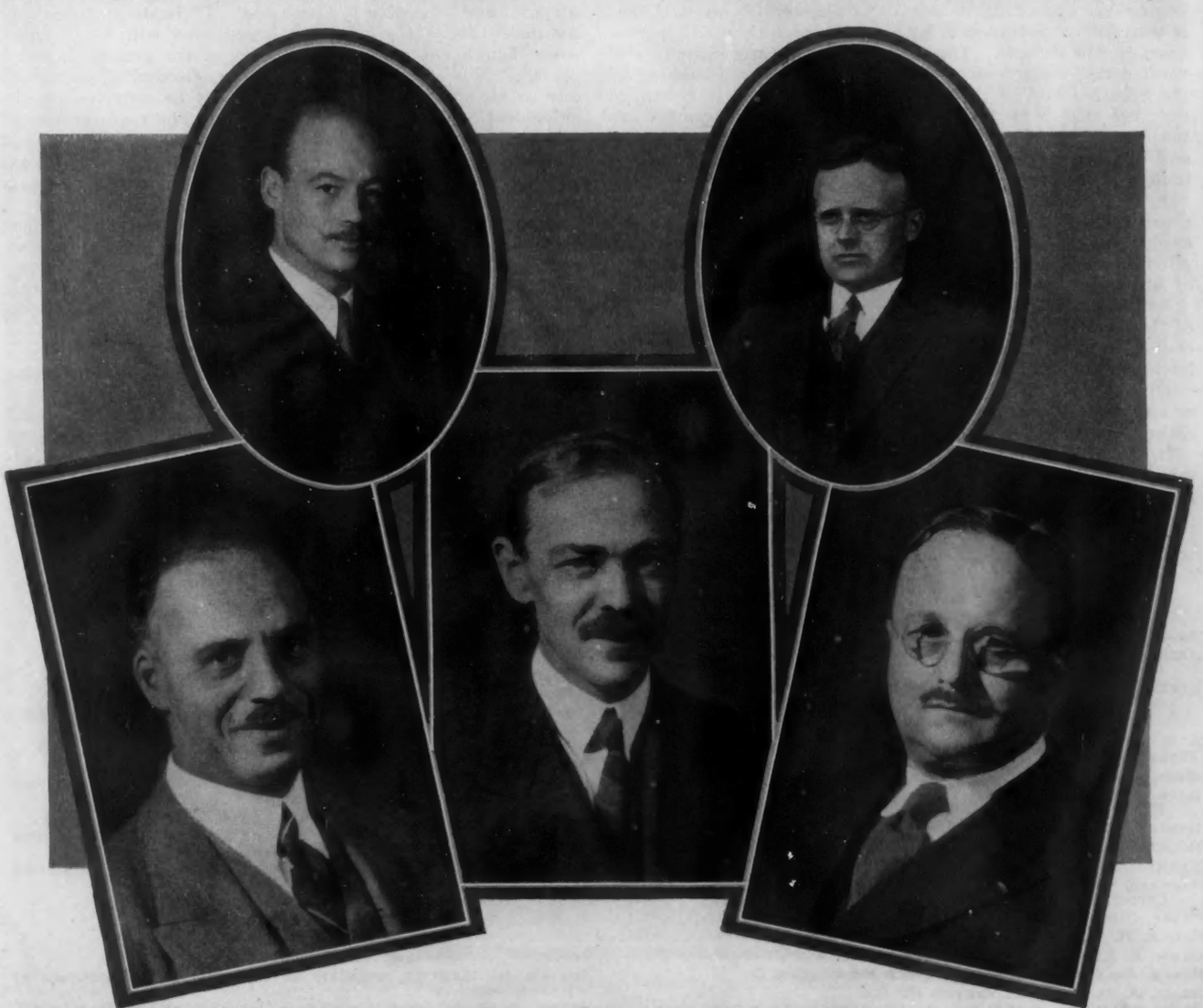
Engine Performance, Calculated and Actual, and it presented in outline a method of predicting the power output of a given aircraft engine equipped with a direct gear-driven centrifugal supercharger. The calculations were based on the fundamental assumptions common to internal-combustion engineering. Three superchargers of different ratings were considered for the purpose of selecting the one which would give the best all-round performance. Consideration of weight, compactness, mechanical reliability, simplicity and general arrangement are factors in the selection of the best rating. The effect of superchargers of various ratings on engine power-output, as well as the effect of various factors on engine performance, were shown in curve form.

Tests of a supercharged Curtiss D-12 engine were conducted in the altitude chamber by the Bureau of Standards and the results were compared with the calculated results obtained by the method outlined. The conclusions reached are that, for all-round performance up to a definite altitude, an intermediate supercharger rating should be selected, and that the performance of engines equipped with direct-driven centrifugal superchargers can be predicted with a fair degree of accuracy in the manner described. The paper in full is printed elsewhere in this issue of THE JOURNAL.

Supplementing the paper, Mr. Chenoweth and also E. T. Jones, chief powerplant engineer for the Wright Aeronautical Corporation, discussed the respective characteristics of the gear-driven supercharger, the turbo-supercharger and the Roots-blower type of supercharger. The general shape of the curve obtained with the Roots-blower type of supercharger would, in Mr. Chenoweth's opinion, be similar to that of the curves shown in his paper. It was said by Mr. Jones that, qualitatively, the efficiency of the Roots-type supercharger generally will be lower than that obtained with the gear-driven centrifugal type. He said also that, with the latter type, he believes that slightly better power is obtained near the ground and slightly poorer power at altitude. With the turbo-supercharger, in his opinion, there should be no change in the engine power at any altitude up to the rating of the supercharger except that due to increase in temperature.

Sanford A. Moss, of the Thomson research laboratory of the General Electric Co., commented at length upon Mr. Chenoweth's paper. He stated that the fact must not be lost sight of that the over-all effect of the use of a centrifugal supercharger is to give a very appreciable gain in the performance of the engine and of the airplane at altitude, with very little additional complication.

It was said by H. K. Cummings, of the Bureau of Standards, that a determination of ideal supercharging had been made recently by the Bureau. Two different engines were tested in the altitude chamber without an actual super-



AMONG THE 400 WHO ATTENDED THE MEETING WERE

Commander J. C. Hunsaker (Upper Left); H. E. Mahan (Upper Right), Who Discussed Airport Lighting at the Night Session at Hadley Airport; L. M. Woolson (Lower Left); Arthur M. Halsted (Lower Center); and Lorillard Spencer (Lower Right)

charger, in each test, but under supercharging conditions. Instead of reducing the pressure at the carbureter intake to correspond with each altitude, the air was introduced at atmospheric pressure, thereby providing complete supercharging at all the altitudes considered in the test.

Operation of the Wright Whirlwind Engine

In the paper by C. H. Biddlecombe, aeronautic transportation engineer, New York City, and formerly operations manager of the Colonial Air Transport, Inc., is recounted the experience obtained with the Wright Whirlwind engine for 13 months of flying operation over the Boston and New York City air-mail route. A total aircraft-flying time of 2146 hr. 35 min. is represented, or about 193,000 air-miles. The paper describes the three types of airplane used and gives details of the commercial operation of the engine; it is printed elsewhere in this issue of THE JOURNAL.

In the discussion following the paper, Chairman Crane related interesting features of the early development of the engine under discussion and commented also on the respective merits of single-engine and multi-engine airplanes. He mentioned the fact that the possibilities of failure increase greatly as the complication of the powerplant increases.

F. B. Rentschler, of the Pratt & Whitney Co., mentioned some of the characteristics of the Wasp aircraft engine made by this company. He said in part that the 200-hp. radial engine has proved itself worthy in commercial use and that it was still uncertain just how much larger than 400 hp. the engines will become. The present engineering experimental work done by his company is, he said, largely influenced by the requirements of the Navy. In his opinion, it is fair to say that engines at least up to 2000-cu. in. displacement are feasible in the form of single engines. Beyond that capacity, and with supercharging, it is difficult to determine what the limitation of power may be.

R. W. A. Brewer, consulting engineer, remarked on the present successful operation of the air-cooled radial aircraft-engine in general. He emphasized that facility and simplicity are attributes of maintenance work, and showed slides of an engine especially designed to make maintenance easy.

Archibald Black, consulting air-transport engineer, spoke of the depreciation rate of the Whirlwind engine and the fact that it is based on a 1000-hr. life. He stated that recently he increased that life to 1250 hr. for calculation purposes, while still maintaining 25 per cent depreciation. As to the estimates of operating costs stated in the paper, Mr. Black called attention to the need for adding the overhead costs.

It was stated by J. H. Geisse, of the Naval Aircraft Factory, Philadelphia, that the air-cooled engines at the aircraft factory have been operated on exactly the same oil and fuels as have the water-cooled engines. He said that, while it is true that an air-cooled engine is more susceptible to damage because of using a poor fuel than is a water-cooled engine, the actual requirements of the two are determined more by the compression ratio than by anything else.

City Planning for Airports

Airports and airways in relation to city planning and to regional planning were considered by John Nolen, Cambridge, Mass., in the paper he presented. After stating the general considerations relative to the subject, he discussed first the subject of whether airways should determine the location of airports or the airports should determine the location of the airways. Mainly, it seems that airports will determine the location of the airways, especially as the development of the airplane comes at a time when the principal cities of the country are well established. He said that an airport has been defined as any locality either of water or land that is adapted for the landing and taking off of aircraft and which provides facilities for shelter, supply and repair of aircraft; or a place used regularly for receiving or discharging passengers or cargo transported through the air.

Two major points must be considered in the location of airports or landing-fields. The first is the selection of the cities, towns, or places in the open country that will be directly on the air route and form an integral part of the airport and the airways systems. Ultimately, it can be assumed that every place of importance will be included, even though not all may be a part of the general airways service. The other main point is the selection of the actual site or sites in a given city or town to be acquired for development as airports or landing-fields. The requirements of all aircraft, that is, airplanes, airships, seaplanes and balloons, should be included. The general recommendations are influenced by geographical location, climatology, topography, soil conditions and by drainage.

Other features that require careful consideration include size, accessibility with regard to main-highway connections, railroad facilities and the like, cost and ownership, and accessory features. The last mentioned includes incidental buildings and adjacent open spaces for the parking of automobiles. A liberal marginal allowance of land should be obtained to provide for future expansion.

Supplementing Mr. Nolen's paper, the legal phases relating to airports were discussed by Frank B. Williams, who is connected with the Regional Plan for New York City. His comments concerned the problem of acquisition of property, such as whether a city has the right to acquire property outside its boundaries or outside the State in which it is located, and similar matters.

1927 Aeronautic Meeting Registration

ADAMS, BURNHAM, engineer, Wright Aeronautical Corporation
ALDRIN, LIEUT. E. E., U. S. A., assistant chief of the airplane branch of the materiel division, Air Corps
ALEXANDER, W. V., JR., staff engineer's office, American Telephone & Telegraph Co.
AUG, WILLIAM F., student, New York University
AVERY, W. R., engineer, Gillette & Malcomson
AZCARATE, JUAN F., aeronautical engineer, New York City
BABIKOFF, V. V., engineering department, Babcock-Wilcox Co.
BACKUS, HAROLD A., materials department, Curtiss Aeroplane & Motor Co., Inc.
BAISLEY, SECOND-LIEUT. H. K., U. S. A., Air Corps
BALKELARD, GEORGE, assistant to president, Bakelite Corporation
BAKKEN, H. E., United States Aluminum Co.
BARNARD, S. B., airplane engine designer, Fairchild Caminez Engine Corporation
BARRY, CAPT. R. B., Air Corps Reserve
BAUGH, H. V., general inspector of naval aircraft
BAUM, S. J., manager of the aeronautic division, Brewster & Co.
BEACH, STANLEY Y., president, Beach Engineering Co.
BEALL, A. L., engineer, Vacuum Oil Co.
BEARD, M. GOULD, installation engineer, Fairchild Caminez Engine Corporation
BEISEL, REX B., design engineer, Curtiss Aeroplane & Motor Co., Inc.
BELL, J. T. R., Rollway Bearing Co.
BERGH, R. C., student, New York University
BERGMANN, A. C., general manager, C. G. Spring & Bumper Co.
BETANCOURT, G., engineer, Aircraft Development Corporation
BETRAN, C., engineer, Brewster & Co.
BIDDLECOMBE, C. H., consulting air transport engineer, New York City
BLACK, A., consulting air transport engineer, Garden City, N. Y.
BLACK, DONALD R., structural engineer, Patrick McGovern, Inc.
BLACKWOOD, A. J., research laboratory, Standard Oil Co. of New Jersey
BLYTHE, R. R., Bruno-Blythe & Associates
BOEHM, A. BRUCE, lubrication engineer, Standard Oil Co. of New Jersey
BOULTON, B. C., chief engineer, Loening Aeronautical Engineering Corporation
BOWEN, R. SIDNEY, JR., managing editor, *Aviation*
BRADY, G. W., Chance Vought Aircraft Corporation
BREWER, R. W. A., consulting engineer, Philadelphia
BROCK, W. S., manager, Wayco Air Service, Inc.
BROOKS, A. RAYMOND, associate airways engineer, Department of Commerce
BROWN, A. T., mechanical engineer, Public Service Production Co.
BROWN, SANFORD, director of engineering, Bakelite Corporation
BROWN, W. G., professor, Massachusetts Institute of Technology
BRUNO, HARRY, Bruno-Blythe & Associates

Speakers and Discussers at the Thursday Session

Capt. C. H. Biddlecombe (Upper Left), Who Discussed Maintenance of Wright Air-Cooled Engines in Commercial Operation; Opie Chenoweth (Upper Center), Who Discussed Supercharged Engines; John Nolen (Upper Right), Who Discussed the Place of an Airport in a City Plan; and Capt. R. W. A. Brewer (Middle Left), S. A. Moss (Center), G. A. Rentschler, Jr. (Middle Right), Frank B. Williams (Lower Left), H. K. Cummings (Lower Middle), and David Darrin (Lower Right), Who Took Part in the General Discussion

BUEL, HILLHOUSE, consulting engineer, New York City
BURNELLI, VINCENT J., chief engineer, R. B. Corporation
BYCE, L. D., works superintendent, Ottawa Car Mfg. Co.
CALKIN, L. P., sales department, Phillips Petroleum Co.
CALKINS, C. H., chief engineer, Baush Machine Tool Co.
CAMINEZ, H., chief engineer, Fairchild Caminez Engine Corporation
CARBONARA, V. E., assistant chief engineer, Pioneer Instrument Co.
CASAMASSA, A. M., Schaap Co.
CAUTLEY, JOHN R., Bendix Brake Co.
CHAIRMAN, IRVING J., airplane engineer, New York City
CHASE, C. N., sales engineer, Westinghouse Electric & Mfg. Co.
CHASE, JULIAN, business manager, *Automotive Industries*
CHATFIELD, C. H., associate professor of aeronautics, Massachusetts Institute of Technology
CHENOWETH, OPIE, research engineer, Air Corps
CLARK, E. F., assistant to transportation sales manager, Westinghouse Electric & Mfg. Co.
CLARKSON, C. F., general manager, Society of Automotive Engineers, Inc.
CLAY, N. S., engineer, Westinghouse Electric & Mfg. Co.
CLAYTON, WALTER C., draftsman, Atlantic Aircraft Co.
CLEON, GEORGE C., student, New York University
COLEMAN, C. T., manager truck and motorcoach division of the sales department, General Motors Export Co.
COLUM, HENRY F., factory manager, Pioneer Instrument Co.
COLVIN, FRED H., editor, *American Machinist*
CONDIT, K. H., editor, *American Machinist*
COONRADT, A. C., student, New York University
COOPER, RAY, assistant secretary for aeronautics, Detroit Board of Commerce
CORN, H. I., vice-president, Daniel Guggenheim Fund for the Promotion of Aeronautics
COWLES, L. C., president, C. Cowles & Co.
COX, RAY J., engineer, Gould & Eberhardt
CRANE, H. M., technical assistant to president, General Motors Corporation
CROWNE, I. H., engineer of tests, Brooklyn Edison Co., Inc.
CUMMINGS, H. K., associate physicist, Bureau of Standards
CUMNER, A. B., director of maintenance, Yellow Truck & Coach Mfg. Co.
CUNTZ, J. H., Hoboken, N. J.
DARRIN, DAVID, construction engineer, Thompson-Starrett Co.
DART, EDWARD W., engineer, automotive laboratories, Texas Co.
DAVIDSON, W. F., director of research, Brooklyn Edison Co., Inc.
DAY, CHARLES H., consulting engineer, New York City
DEGEN, A. W., assistant manager of the service department, General Motors Truck Co.
DEGEN, L. K., mechanic, Photomaton, Inc.
DEMOULT, E. A., engineering assistant, Western Union Telegraph Co.
DEN TEX, N., chief engineer, Oertz Streamline Rudder Syndicate
DEPEW, RICHARD H., JR., sales manager, Fairchild Airplane Mfg. Corporation
DICKINSON, DR. H. C., physicist, Bureau of Standards
DOBBINS, ROBERT N., White Co.
DOLAN, PAUL, student, New York University
DOWELL, C. P., engineer, National Aero Corporation
DRAKE, CHARLES L., automotive division of the sales department, SKF Industries, Inc.
DUDLEY, A. S., manager, Sacramento Chamber of Commerce
DUGGAN, T. O., merchandising director, National Standard Parts Association
DURBIN, PAUL C., industrial engineer, Western Electric Co.
DURLAND, H. S., service engineer, American Laundry Machinery Co.
EVANS, EARLE W., research engineer, Standard Oil Co.
EVANS, JOSEPH I., vice-president, Bart Reflector Co.
FAGAN, T. Z., vice-president, Scintilla Magneto Co.
FALES, HERBERT G., operating department, International Nickel Co.
FINGER, S. C., production department, Atlantic Aircraft Corporation
FISK, WILLIAM G., commercial engineer, Radio Corporation of America
FITZGERALD, J. J., inventor, New York City
FLOOD, FIRST-LIEUT. ALBERT E., Air Corps Reserve
FOKKER, A. H. G., president, Fokker Aircraft Corporation
FORWARD, C. B., president, Oil Refining & Development Co.
FOWLER, HARLAN D., engineer, Industrial Motors
FREYMAN, A. W., general manager, Freymanson Engineering Co.
FRIED, JEROME A., treasurer, Thomas-Morse Aircraft Corporation
FULTON, R. W., manager of the aviation division, Tide Water Oil Co.
GANNETT, ROBERT, sales engineer, Eclipse Machine Co.
GASSNER, ALFRED A., project engineer, Atlantic Aircraft Corporation
GRISSE, J. H., chief engineer of the aeronautical engineering laboratory, Naval Aircraft Factory
GERLI, PAUL, merchant, New York City
GIBSON, A. R., General Motors Corporation
GOLL, FRANK D., sales engineer, Aluminum Co. of America
GOURLIE, J. C., editor, *Automotive Industries*
GRANT, R. R., Dayton, Ohio
GRIEME, FRED W., managing director, Billings Aviation Field, Inc.
GRIES, HENRY, Stone & Webster, Inc.
GRONQUIST, C. H., draftsman, Robinson & Steinman
GURNEY, E. R., engineer, International Motor Co.
GWINN, E. S., Turner Construction Co.
HAAS, LIEUT. L., U. S. N.
HALL, A. M., vice-president, Hall-Aluminum Aircraft Corporation
HALL, CHARLES W., president and chief engineer, Hall-Aluminum Aircraft Corporation
HALSTED, ARTHUR M., associate engineer, Bureau of Standards
HAMILTON, ERWIN H., assistant professor of aeronautical engineering, New York University
HAMILTON, W. G., president, Interflash Signal Corporation
HAMON, A. J. M., equipment engineer, E. L. Phillips & Co.
HANDLER, A., manager, Aluminum Co. of America
HANSCOM, C. D., consulting engineer, Denville, N. J.
HARPER, LIEUT. C. B., U. S. N., chief engineer, Naval Aircraft Factory
HARRISON, C. A., Aviation Publishing Corporation
HASBROUCK, A., consulting engineer, New Haven, Conn.
HASBROUCK, JOHN S., experimental engineer, Texas Oil Co.
HAUCKE, OSWIN, superintendent of equipment, Reid Ice Cream Corporation
HENGERER, E. H., Port of New York Authority
HEYWOOD, C. E., manager, meetings and sections department, Society of Automotive Engineers, Inc.
HILDRITH, JOSEPH S., vice-president, Chilton-Class Journal Co.
HINGSBURG, FRED C., chief engineer of the airways division, Department of Commerce
HORCHLER, BENNETT H., representative, Aviation Publishing Co.
HORCHLER, MARTIN H., salesman, William Whitman Co.
HOUSE, FRANK R., engineer, Sperry Gyroscope Co.
HOWELL, K. J., engineering department, Studebaker Corporation of America
HUNSACKER, J. C., engineer, Bell Telephone Laboratories
HUNT, J. H., Chevrolet Motor Co.
HUSTED, D. R., engineer, L. A. Thompson Scenic Railway Co.
HUTCHINSON, R A., sales department, Aluminum Co. of America
HUTCHISON, ARTHUR E., service engineer, Simplex Piston Ring Co.
IFE, WALTER W., executive special agent, National Surety Co.
IRELAND, G. S., president, Ireland Aircraft, Inc.
IRWIN, R. R., vice-president and sales manager, Sauzedde Corporation
JACOBUS, F. L., White Co.
JAMES, A. L., student, New York University
JENNINGS, HENRY, General Motors Corporation
JOBSON, C. D., sales engineer, Sperry Gyroscope Co.
JOHNSON, J. V., designer, bridge engineer's office, Erie Railroad Co.
JONES, E. T., chief engineer, Wright Aeronautical Corporation
KARLSON, G. V., superintendent, Interflash Signal Co.
KELLEMS, EDGAR E., engineer, American Telephone & Telegraph Co.
KIMBALL, JAMES H., meteorologist, Weather Bureau
KIMBALL, L. B., consulting engineer, New Haven, Conn.
KINGSTON, EARLE G., junior partner and engineer, John P. Kingston & Son
KLEMIN, ALEXANDER, professor of aeronautics, New York University
KOELBLE, EDNA, New York City
KOEPPEN, ERNST, Junkers Corporation of America
KROTZ, A. S., General Motors Export Co.
KUGLER, H. M., Taylor Instrument Co.
KURT, FRANKLIN T., assistant manager, Dennison Aircraft Corporation
LANE, ABBOT A., assistant mechanical engineer, Public Service Production Co.
LASCUSAN, ANGEL, New York City
LEE, JOHN G., aeronautical engineer, Fairchild Airplane Mfg. Co.
LENTENTZ, H. C., radio engineer, Radio Corporation of America
LEPAGE, W. L., assistant general manager, Pitcairn Aviation, Inc.
LILJEROTH, S. H., engineer, International Motor Co.
LOTT, E. P., manager of operations, National Air Transport, Inc.
LOWE, E. F., general manager, K. P. Products Co.
LUNDE, OTTO H., instructor, New York University
LUNDT, E. C., engineer, Consolidated Gas Co. of New York
LYNCH, FIRST-LIEUT. CHARLES C., Air Corps Reserve
MABLEY, C. R., Michigan district manager, SKF Industries, Inc.
MACGAHAN, PAUL, engineer, Westinghouse Electric & Mfg. Co.
MACHAROW, C. L., aeronautical photographer, Fairchild Aerial Survey, Inc.
MACNEIL, CHARLES I., experimental engineer, Eclipse Machine Co.
MAHAN, H. E., engineer, General Electric Co.
MALYCHEVITCH, O. A., engineer, Amtorg Trading Corporation
MARBURG, LOUIS C., secretary and treasurer, Marburg Bros., Inc.
MARIGOLD, R., designer, Robert Bosch Magneto Co.
MARRA D., student, New York University
MCCARTHY, C. J., engineering executive, Chance Vought Aircraft Corporation
MCCONKEY, J. F., West Coast representative, Sperry Gyroscope Corporation

McGOWAN, LIEUT. KENNETH P., chairman of aviation group, Air Service Association
McGUIRE, J. C., JR., assistant engineer, Port of New York Authority
MEDVEDEFF, N. J., aeronautical engineer, Sikorsky Mfg. Co.
MESINGER, F. W., sales engineer, Norma-Hoffmann Bearings Corporation
MEYER, WILLIAM H., JR., sales executive, Fairchild Aerial Survey, Inc.
MILLER, HENRY J., mechanical draftsman, International Motor Co.
MILLER, JOHN M., president, Miller Corporation
MILLER, SPENCER, South Orange, N. J.
MILLS, J. E., aviation department, Phillips Petroleum Co.
MINGOS, HOWARD L., Loening Aeronautical Engineering Corporation
MOCK, RICHARD M., technical editor, *Aviation*
MOORMAN, IVAN G., United States Army officer
MORSE, A. L., assistant engineer, Atlantic Aircraft Corporation
MOSES, E. I., lawyer, Moses & Notte
MOSLER, A. R., treasurer, Mosler Metal Products Corporation
MOSS, S. A., research engineer, General Electric Co.
MUNN, E. O., Aeronautical Chamber of Commerce
MURPHY, MISS J. M., inventor, New York City
MURPHY, W. A., field engineer, Rosoff Engineering Co.
NAGEL, C. F., JR., assistant technical director, Aluminum Co. of America
NARDONE, R. M., designer, Eclipse Machine Co.
NEELEY, J. C., New York City
NEILL, THOMAS, engineer, Bureau of Standards
NELSON, JOHN H., research engineer, Wyman-Gordon Co.
NEWELL, JOSEPH S., instructor, Massachusetts Institute of Technology
NEY, A. M., engineer designer, C. H. Matthiessen, Jr.
NOLEN, JOHN, landscape architect and city planner
NOMBURG, MACK, City News Association
OGAWA, YOSHIO, automotive engineer, Uppercu-Cadillac Corporation
O'HARA, RAYMOND A., assistant engineer, Regional Plan of New York
OKADA, J., inspector for aviation, New York City
ORR, GEORGE H., New York City
OSBORN, EARL D., president, Aviation Publishing Co.
OVERLOCK, R. F., lubricating engineer, Pure Oil Co.
PACK, M. N., student, New York City
PAGE, VICTOR W., consulting engineer, Stamford, Conn.
PAINTER, J. H., salesman, Aluminum Co. of America
PALENE, LEW R., National Safety Council
PALMEDO, ROLAND, Lehman Bros.
PARKER, A. G., engineer, C. H. Matthiessen, Jr.
PARKER, WILLIAM, test pilot, Phillips Petroleum Co.
PATTERSON, HUGH M., master mechanic, Connecticut Co.
PAULSON, GEORGE M., chief engineer, B. G. Corporation
PAULUS, A., commercial engineer, Westinghouse Lamp Co.
PEARCE, JOHN D., JR., field engineer, Pioneer Instrument Co.
PEDU, ALEXANDER A., manager, Air Transport Equipment, Inc.
PEPER, W. S., service manager, General Motors Truck Co.
PEPSOON, P. G., sales engineer, Pure Oil Co.
PERKINS, J. M., assistant production manager, Lyddon & Hanford
PERRIN, J. G., consulting engineer, Springfield, Mass.
PETTY, JOHN H., engineer, Petroleum Heat & Power Co.
PICCARD, JULES E., assistant designing engineer, Curtiss Aeroplane & Motor Co., Inc.
PIERCE, R. C., consulting engineer, Bronxville, N. Y.
PIERCE, R. T., instrument section head, Westinghouse Electric & Mfg. Co.
POND, S. L., Keystone Aircraft Co.
POPE, E. F., treasurer, Hall Aluminum Aircraft Corporation
POWERS, CHARLES R., engineer, Gembers Corporation
PUFFER, S. R., engineer, General Electric Co.
RAABE, A. C., sales department, Eclipse Machine Co.
RAUCH, CHARLES W., assistant chief engineer, Standard Steel & Bearings Co., Inc.
REEL, MAJOR GORDON, Air Corps Reserve
REMEY, JOHN T., research engineer, New York City
REMIG, P. W., JR., engineer, Vacuum Oil Co.
RICHARDSON, F. E., automotive engineer, Vacuum Oil Co.
RITCH, HENRY C., aviation lighting specialist, General Electric Co.
RITTER, HAROLD J., district manager, Norma-Hoffmann Bearings Corporation
ROBINSON, ERNEST, vice-president, Fairchild Aviation Corporation
ROCHÉ, J. A., senior aeronautical engineer, Air Corps
ROGERS, WILLIAM A., advertising manager, *Aero Digest*
ROHLFS, ROLAND, sales manager, Claude Neon Lights, Inc.
ROHRICH, GEORGE, New York City
ROSS, O. A., consulting engineer, New York City
ROVERE, L. H., engineer, Western Union Telegraph Co.
RUBERT, K. F., New York City
RUMBALL, F. G., sales engineer, Timken Roller Bearing Co.
SALOMON, T. G., New York City
SASAKI, M., student, Massachusetts Institute of Technology
SCHAAP, A. K., JR., general manager, R. S. Schaap, Jr.
SCHAAP, ROBERT S., R. S. Schaap, Jr.
SCHERER, J. OTTO, chief engineer, Junkers Corporation of America
SCHICKEL, NORBERT H., consulting engineer, Stamford, Conn.
SCHINDLER, CORNEL, draftsman, Sikorsky Mfg. Corporation
SCHLEE, E. F., Wayco Air Service
SCHOLZ, GEORGE A., manager of the goggle department, E. B. Meyrowitz Co.
SCHULTHEIS, E. M., automotive engineer, Timken Roller Bearing Co.
SCHUVALKY, O., Lehman Bros.
SERGEANT, CHARLES H., consulting engineer, New York City
SEYMOUR, L. D., chief engineer, National Air Transport, Inc.
SHERBUNDY, E. H., Cleveland
SHIELDS, HENRY B., layout draftsman, International Motor Co.
SHIELDS, WILLIAM, engineer, Indian Motocycle Co.
SHOEMAKER, F. G., research engineer, H. H. Franklin Mfg. Co.
SHOOP, R. M., sales engineer, General Electric Co.
SHOPE, L. R., advertising
SIKORSKY, I., president, Sikorsky Aero Engineering Corporation
SINITZIN, N., aeronautical engineer, Sikorsky Mfg. Corporation
SKINNER, ARTHUR A., sales engineer, Leece-Neville Co.
SMITH, LAWRENCE V., chief engineer, B B T Corporation of America
SMITH, W. L., superintendent of the eastern division, National Air Transport, Inc.
SNOW, HOWARD, engineer, Fairchild Aviation Corporation
SONNEK, P. FRANK, patent attorney, New York City
SPEIR, GODFREY B., engineer, Vacuum Oil Co.
SPENCER, LORILLARD, president, Atlantic Aircraft Corporation
STALB, A. R., engineer, Fairchild Aviation Corporation
STAY, T. D., technical supervisor, casting division, Aluminum Co. of America
STEDMAN, E. W., chief aeronautical engineer, Royal Canadian Air Force
STEENSON, JAMES, executive engineer, Fairchild Airplane Mfg. Co.
STEPHENSON, PHILIP, engineering department, Chance Vought Aircraft Corporation
STOUT, WILLIAM B., vice-president and general manager, Stout Metal Airplane division, Ford Motor Co.
STREETER, R. L., Aluminum Co. of America
STROOP, D. V., Bureau of Standards
SULLIVAN, H. ALLAN, Daniel Guggenheim Fund for the Promotion of Aeronautics
SWIFT, W. K., salesman, Bound Brook Oilless Bearing Co.
TAYLOR, JAMES B., JR., president, Upressit Products Corporation
TAYLOR, P. B., assistant engineer, Wright Aeronautical Corporation
TITTERTON, GEORGE F., New York University
TRUSCOTT, STARR, aeronautical engineer, National Advisory Committee for Aeronautics
VALENTINE, F. E., designing engineer, General Electric Co.
VAN DER BECK, JOSEPH, salesman, Standard Oil Co.
VEAL, C. B., research manager, Society of Automotive Engineers, Inc.
VERTIZ, F., New York City
VON DEBSTER, A. P., civil engineer, City of Los Angeles
VON WALDY, J., president, Industrial Motors
WARNER, EDWARD P., assistant secretary of the Navy for aeronautics
WARNER, JOHN A. C., assistant research engineer, Studebaker Corporation of America
WATTER, MICHAEL, technical design engineer, Chance Vought Aircraft Corporation
WEATHERBEY, VAUGHAN I., engineer, Wright Aeronautical Corporation
WEBSTER, R. C., engineer, Kinney Mfg. Co.
WELLS, D. H., engineer, International Motor Co.
WHIT, LAWRENCE B., general manufacturing department, General Motors Export Co.
WHITTELSEY, C. B., president, Hartford Rubber Works Co.
WHITTELSEY, C. B. JR., assistant to general manager, Society of Automotive Engineers, Inc.
WHYTLAW, JOHN G., JR., F. B. Keech & Co.
WILD, J. E., vice-president, Robert Bosch Magneto Co.
WILLARD, R. M., sales engineer, Aluminum Co. of America
WILLS, HALSEY W., Warren & Wills
WITBECK, ROBERT, Taylor Atkins Paper Co.
WOLLMAR, L., manager, Robert Bosch Magneto Co.
WOOLSON, L. M., aeronautical engineer, Packard Motor Car Co.
WRIGHT, H. H., insurance, New York City
YOUNG, CLARENCE M., director of aeronautics, Department of Commerce
YOUNG, R. W., experimental test engineer, Wright Aeronautical Corporation
ZIMMERMAN, W. F., accountant, New York City
ZIMMERMANN, PAUL G., Mystic, Conn.

CHARLES MATTHEWS MANLY

IN the passing of Charles Matthews Manly the Society and the industry have suffered great and irreparable loss. A man of great native ability and thoroughly devoted to good principles, he was a master of friendship; a master of fair dealing; a master of courage; a master of work.

A pioneer in aviation, a wholehearted disciple of science and scientific methods, he had amazingly comprehensive knowledge of the almost unlimited number of phases of automotive engineering. The Society never had a better, more intelligent, more effective, or more helpful friend. He was a tireless worker, exerting tremendous long-sustained energy in analyzing problems and in formulating elucidations and deductions relating to them.

He served the Society in a surprising number of capacities. The S.A.E., so frequently in his thoughts, was very dear to him and was a major interest in his life. He always advocated straightforward approach and getting things done, regardless of precedent when necessary. He was President of the Society in 1919. The Society has had no more earnest or capable President. He divined and set forth clearly its functions and the methods it should pursue.

During his presidency, he laid the groundwork for the present Operation and Maintenance movement of the Society. In his 1919 presidential address he said on the subject of the need for engineering in operation:

> The work of the automotive engineer is not finished, but merely begun, when the machines are designed and built, whether they be motor-trucks, tractors, aircraft or other vehicles. There is more need today for real engineering work in connection with the planning and organization of the operating end of automotive vehicles and machines than there is in connection with the design and construction of them, just as there are more engineers engaged in the operating and maintenance end of railroads than are engaged in the design and construction of locomotives and railroad cars.
>
> In the subdivision of automotive engineering work having to do with motor-trucks, the real work of the engineer has hardly as yet been begun. True it is that motor-trucks are being sold and are daily hauling thousands of tons of merchandise and general freight, but the careful study and collection of data for accurately predetermining the best operating equipment, organization and personnel to meet given conditions at a definitely predetermined cost has hardly been started. This single phase of automotive engineering presents more problems for the engineer to solve than would be needed if all our records and data in railroad transportation engineering were suddenly swept away and it became necessary to reestablish such data immediately for the determination of proper freight rates.

In this same address, he said of standardization, of which he was a most aggressive proponent: "The S.A.E. has done more to show the importance and economic value of standardization, both to the producer and the consumer, than any other single organization in the world."

Mr. Manly was a pillar in the standardization work of the Society. During many years he was a member of various divisions of the Standards Committee, as well as its Vice-Chairman. He presided at many meetings of the Standards Committee. During the World War he represented the Society in aeronautic standardization activities both in this Country and abroad. His work on the Patents Committee and on the Standardization Policy Committee was of great value. He was well informed on patent matters, as well as on engineering; and was an excellent logician. It has been said of him as an engineering expert witness that he was "in a class by himself." He had been one of the representatives and the principal spokesman of the Society on the American Engineering Standards Committee since the inauguration of that Committee. In his discussions of complicated phases of national and international standardization and cooperation he showed a very high order of understanding and ability. He was without a peer in this field of work.

Mr. Manly was born at Staunton, Va., in 1876. He was graduated at Furman University as master of mathematics and mathematical physics; and at Cornell University as mechanical engineer. He was engineer in charge of aviation research work for the United States Government under Prof. Samuel P. Langley at the Smithsonian Institution, City of Washington, from June, 1898, to April, 1905. He designed and built the Langley flying-machine and the gasoline engine therefor. This engine was of great significance, in view of its light weight and general characteristics, as a forerunner of developments thereafter. In 1901 the development of the internal-combustion engine was still so slight that it did not admit of the construction by any European maker of an engine weighing less than 12 lb. per hp. The five-cylinder radial-type engine built by Mr. Manly was characterized by design and workmanship which showed a remarkable advance in construction. At 950 r.p.m. it developed 52.4 hp., weighing only 2.4 lb. per hp., a weight per horsepower record not equalled until the building of the 400-hp. Liberty engine. In addition to its other achievements the engine pointed the way to the development of other than the vertical-type engine. In building this engine Mr. Manly showed not only his inventive genius but an ability to cope with the lack of manufacturing methods and facilities. Later he was engaged in automobile engineering, especially relative to transmissions of the hydraulic type, for which he held patents. During the World War he was consulting engineer, chief inspection engineer and assistant general manager of the Curtiss Aeroplane & Motor Co. Another war activity was his work with the British War Office. Mr. Manly designed the first multi-engine airplane bomber which not only met but surpassed the specifications laid down. The bomber was known as The Canada and had a total power of 500 hp.

He was the editor of the Langley Memoir on Mechanical Flight, which was published in Vol. 27 of Smithsonian Contributions to Knowledge. He had the greatest admiration for Dr. Langley and devoted a great deal of time to making clear what credit Dr. Langley was entitled to in the solution of problems of flight of heavier-than-air craft. He believed thoroughly that the Langley machine was capable of flight. Undoubtedly, Mr. Manly was one of a half-dozen early pioneers who did most to develop heavier-than-air craft before it was generally understood that flight of such craft is possible. In recognition of his work in this field he was elected an honorary member of the National Aeronautic Association.

Mr. Manly died last month at Kew Gardens, Long Island, of acute indigestion. He is survived by, in addition to his mother, two sons, two brothers and four sisters.

He was a keenly interested attendant at Society and Metropolitan Section meetings for many years. At the first meeting of the Society held subsequent to his death, the Aeronautic Meeting last month, the following resolution was passed:

> WHEREAS, the members of the Society of Automotive Engineers are deeply conscious of the irreparable loss they have suffered in the passing of Charles Matthews Manly, and
>
> WHEREAS, the services of Mr. Manly to the aeronautical art can never be overestimated and should never be forgotten, therefore,
>
> *Be It Resolved*, that the members of the Society in Aeronautical Meeting assembled desire to make expression of their own grief and of their sympathy with the family of Mr. Manly.

Mr. Manly was very near and dear to many, including the office staff of the Society, whom he was always most generous in assisting. These will long remember this noble man.

CHARLES MATTHEWS MANLY

Application of Non-Military Aircraft to Naval Purposes

By EDWARD P. WARNER[1]

AERONAUTIC MEETING PAPER

Preparedness of the aircraft industry for rapid production of service machines in event of an international war are discussed.

More than most industries, the aircraft industry is in close touch with requirements of the Army and the Navy, largely because it has, up to the present, made use of engines and aircraft designs developed in conjunction with the Services.

Light commercial-aircraft are now being built in rapidly increasing numbers, and emphasis is laid by the author on the adaptability of these for training purposes and the obligation and privilege of the builders to become informed on how they can supply greatly increased numbers for military training-schools with the least delay and the least shock to their own producing organizations.

Development of a flying-boat industry is an urgent need in this Country, and this type of airplane is well adapted, with but little change, for both war patrol-duty and for peace-time passenger service.

IN the event of international conflict escaping from the stage of peaceful negotiation into a more violent form, the prosecution of war becomes not only the principal but virtually the sole business of the Nation. It becomes the personal concern of every citizen that a threat to the National safety should be repelled and that he personally should lend his utmost energies to that end. No less is it the concern of industrial organizations, great and small, that they should make their contribution. Industry is the aggregate of the human beings that compose it, and should be subject to the same motives that govern the action of the individual. The natural impulses of patriotism are supplemented by the pressure of public opinion, and in the last extremity both the individual and the industry may find their actions brought by statute under complete governmental control. It happened so in every belligerent country in Europe in 1915 and the following years, and to a considerable extent in the United States during the years of our participation in the war.

More than one highly industrialized country participant in that struggle fell under the spell of the slogan "business as usual" in the initial stages of its war effort. The length of time required to discover the fallacy inherent in the words varied directly in proportion to the weight with which the burdens and dangers of war were felt. The war of 1914 to 1918 was, as any future combat would be, an affair of National effort, of nations opposed as such; and the successful prosecution of the war became for the time being the only business of importance. The usual affairs of daily life had significance only as they contributed to the chief end. Usual business was important, not because it was usual, but when, as, and if it furthered the conduct of the war. Services of the individual were conscripted, industries submitted to a control which was in part statutory, in part unofficial, but in all instances as firm and rigorous as was deemed necessary to the prosecution of the business in hand. An outstanding lesson of the war experience was the necessity, in the event of another similar international catastrophe, of a mobilization of industry at least as thorough as and even more promptly put into effect than that of 1917 and 1918.

Preparation for war in time of peace is not a matter of armies and navies alone. It concerns itself equally with the study and analysis of that part of the war machine which is only indirectly military, so that if it is needed its parts may fit together smoothly and its operation be started at full speed with a minimum of wasted time and effort. In 1913 industrial mobilization was nothing but an unfamiliar phrase to the average business man. In 1927 the phrase is connected with a very tangible group of activities, with new relationships between the War and Navy Departments and the Nation's factories, and with new interests and obligations voluntarily assumed by many of the Nation's industries.

AIRCRAFT INDUSTRY IS IN CLOSE TOUCH WITH MILITARY DEVELOPMENTS

The subject is one in which the aircraft industry feels an especially intimate concern. Five years ago the aircraft industry was in a state of perpetual mobilization. Even though it was far below war strength, its attention was concentrated upon military markets at all times. We now have a true commercial industry catering to commercial purchases, but the relationship between military and non-military aircraft is still close, and the builder of airplanes for sport or commerce is still likely to be sufficiently interested in military developments to keep in touch with them, even though he has no expectation of seeking to construct machines for the Navy or Army in time of peace.

In the event of war he would do so as a matter of course, and the transition to war-time status of the aircraft industry, even that part of it which is devoted exclusively to commercial production under normal conditions, although it involves some special problems and difficulties, should in general be far simpler than the turning over of factories normally making an article for which there is no war demand. Commercial and military aircraft are two distinct things. Each group has its

[1] M.S.A.E.—Assistant Secretary of the Navy for Aeronautics, Navy Department, City of Washington.

special characteristics, and as groups they are sufficiently alien to each other so that it is not easy to produce both in a single shop, but there is still a principle in general kinship and purpose. To turn from commercial to military airplanes should be much easier than to turn from making ash trays to making shell cases.

This transition should be made as easy as possible. In planning war-time procurement, it should be the concern of the responsible departments to minimize the shock of transition from peace to war production, both by persuading the companies that may have to make the change to give thought to it and to make their own plans in advance, and by preparing to put to some military use machines closely resembling the straight commercial product wherever that can be made to seem feasible.

Airline Planes Would Not Be Drafted

In no case is it to be expected that the commercial airplane can be put into military service exactly in its original form, except for that rapid transport of men and supplies which is virtually a commercial service, even though carried on immediately behind the zone of battle. In any instance, however, it would be with the current and future production of the industry at the time of the declaration of war, rather than with airplanes then already in use, that plans for conversion would be concerned. No emergency is likely to be so dire as to justify the attempt to muster into the use of the Navy or the Army airplanes already existing and serving commercial ends.

The aircraft industry can be turned over entirely to activities pertaining to the winning of a war, but among those activities is the maintenance of vital services. The slogan of "business as usual" does not justify the diversion of effort to the production and merchandising of luxuries or superfluities in a time of National danger or strain, but, equally, no slogan demands and commonsense would not permit of the abandonment of industries and employments not directly connected with operations in the field but none the less necessary to the preservation of the National life and the maintenance of services behind the lines. The sure and speedy internal transport of mail and passengers would be as important in war as ever in peace, and the closing down of air-transport lines would be a blow to the Nation's military and industrial organizations which would far exceed in importance any benefits that would result from the military application of machines serving to speed urgent communications and time-pressed travelers on their way.

In 1918 no attempt was made to rob American railroads of equipment to be taken away and run over freshly laid tracks in the war zone; yet, with all that could be done, and with the Government having taken over the administration of the railroads to eliminate competition and get the utmost out of the equipment that existed, the pressure of war-time industrial organization upon the transportation system was such that painfully slow movement of freight, and no movement at all of shipments which were less than indispensable to the conduct of the war, became the order of the day. Domestic transport, not to be spared then, could not be molested in any important detail in the future without serious danger of undermining indispensable parts of the industrial structure. In war, as in peace, air transport would go on, and if any change in its scope were made it would have to be an increase.

But air-transport lines alone would not absorb the entire energies of companies building machines for a commercial market, and especially of those building for the particular uses of the private owner or the small operator of taxi and sightseeing services. They might confidently be expected to have something left to spare for production for the direct service of the Navy and Army. The problem that must receive advance consideration, as already indicated, is the facility of the transfer from commercial to military plane construction.

Problem of Transition to War Production

The Morrow Board, foreseeing the conditions of aircraft production in time of war, said in its report:

> The experience of the late war gives concrete illustration of the war-time and post-war problems of an aircraft industry and shows that, in respect of the production of airplanes, an international conflict coming without appreciable warning divides roughly into three successive parts. The first, lasting but a few weeks, is that in which dependence has to be placed on factory equipment and factory personnel actually in the Service, before there has been time to get any program of expansion under way. It is succeeded by a somewhat longer period, during which the aircraft industry, using its existing facilities to the utmost and expanding them as rapidly as possible, delivers new airplanes to the Service at a moderate but steadily increasing rate. In the third and final period, the production of the aircraft industry proper is augmented by the incursion into the airplane field of a wide variety of plants normally engaged in manufacturing such things as pianos, furniture, automobile bodies, fancy hardware, and other articles not vitally necessary in the prosecution of war. When that stage is reached, the rate at which airplanes can be produced in a highly industrialized country like the United States is very great.

The commercial-aircraft industry, not normally concerning itself particularly with military requirements, could be of enormous help in smoothing and expediting the transition from the second into the third stage through its ability to take up a part of the production load while regular military factories were still pressing forward their expansion to a war-time status and while factories with no airplane experience were not far enough advanced in their preparations for conversion to be important contributors to the program.

Non-Military Production Growing Fast

Five years ago the producers for non-military markets cut but little figure and could have been of but little help in emergency. They play a great part in the industry now, and an even greater future lies before them. An unofficial questionnaire has indicated a production, by companies never receiving a production order from the Government, of about 500 light commercial airplanes in 1926. Another inquiry, conducted by a magazine, has revealed actual sales of 1775 machines, most of them in this same class, during the first 8 months of the present year, two-thirds of the total during the three summer months, and still growing! Such figures demand respectful attention in any quarter.

If a builder of furniture or of talking machines is to embark upon the production of airplanes as a new problem, he may be expected, except for a greater familiarity with the working of some materials than of others, to be equally ready to undertake the production of any type. To the newcomer possessed of a plant and an industrial organization but of no specific aeronautical experience, the building of wooden wings and a steel fuselage for a bombing airplane is much the same problem as the building of wooden wings and a steel fuselage for a fighting

or training machine. In any case, special equipment in the shop and a special training of labor are required, and it is necessary to take drawings of a wholly unknown article and follow them; there is no reason to fear one novel problem more than another.

The builder of commercial airplanes finds himself in quite a different case. He starts with a shop, a staff, and jig and tool equipment not merely for building airplanes but for a particular airplane, and it should be axiomatic that his services will be most useful in the development of a program of military-aircraft production if they are applied to work which has a maximum of features of identity with that to which he is habituated.

Unadaptability of Commercial Airplanes

For the fighting machine there is no commercial analogy. There can be no close kinship in detail of design or construction between the airplane constructed for combat service and any intended for a non-military market. Almost the same thing is true of the fast observation types, for their structural strength must be so great and the problems of their construction are so largely those of installation of equipment specifically military as to leave their design necessarily somewhat remote from that of any plane intended for commercial employment. Wings and tail surfaces might be alike in an observation airplane and a fast mail-plane from the hands of the same designer, but, having regard to differences of load factor and other points of variance in the fundamental conditions governing the design, even that is somewhat less than likely.

For heavy bombing service, on the other hand, certain types of commercial craft may prove to be adaptable with but minor modification. There has been evidence of it in the deliberate construction in more than one European factory of airplanes of which only the fuselage, or even nothing but a detachable central section of the fuselage, needed to be changed to convert a passenger carrier into a satisfactory bombing craft. Such a machine, however, is always likely to be less than fully satisfactory in its military employment. Aerial bombing frequently has to be carried on under conditions so arduous that nothing less than the maximum of possible efficiency and performance is to be accepted, and the factors that go to govern efficiency as a bomber are so numerous and are interlocked so closely that it is difficult to incorporate into the assembly any element designed with another set of governing conditions in mind. The wing arrangement that is ideal for passenger carrying may be fatal to satisfactory vision for formation flying, and a landing gear that is excellent for commercial work may leave no space clear for the mounting of a bomb rack.

For the specific purposes of naval aviation, the desirability of ready conversion from landplane to seaplane or of provision for arresting motion on a carrier deck, or both, together with the extreme importance of minimized dimensions on an airplane that is to be carried on shipboard, are unlikely to receive even passing attention in a commercial layout, and indeed could not well do so without loss of commercial efficiency measured in economic terms. Finally, the large transport planes which would be most readily assimilated to bombing conversion are a type for which the market is likely to remain comparatively small, their long life keeping to a low figure the necessary annual replacements even on a very large network of airlines. The industry devoted especially to such machines is unlikely to be so extensively and specially tooled-up for quantity production as to offer a substantial economy in attempting a conversion for bombing service rather than a fresh start on a design substantially or completely new.

In application to Service landplanes and small seaplanes, in short, the idea of direct serviceability of the commercial industry without dislocation and without transfer over to work along new lines seems a will-o'-the-wisp. If the airplane industry that is devoting itself to commercial production is to be turned, in the event of war, to the building of machines immediately suitable for use with the fleet, it is to be turned in most cases to a product having nothing in common with the output of its factory in years of peace, except that both are airplanes.

Naval and Commercial Flying Boats Alike

One specifically naval type of airplane offers a somewhat brighter picture. Those characteristics which make the most efficient flying boat for patrol duty make also, with but little change, the most satisfactory boat for passenger service. When we in America finally awaken to the importance of the flying boat, and when our urgently-needed flying-boat industry is finally resurrected, it requires no special gift of prophecy to foresee that it will be constructing machines for naval and for commercial use side by side, and that there will be, not merely similarity, but almost complete identity between the two, except in certain features of interior arrangement of hull. Within a seaworthy hull-structure of the necessary dimensions for the big boat there is always enough space either for liberal passenger-accommodation or for the mounting of such military equipment as may be required and the accommodation of the crew who use it; and any changes that have to be made in going from the commercial to the naval layout, or vice versa, may be carried out by cutting and fitting above the water-line and without modification of fundamental structure.

The substantial interchangeability of design between many parts of the naval flying boat and that for passenger carrying is of primary importance in that it offers encouragement for the development of an industry and permits an increase of peace-time production which can be geared-up to the total demand from two separate markets, so bringing some economy in manufacture as compared with costs which would exist if each had to be built for only one purpose. It is by no means the flying boat, however, which offers the maximum prospect of speeding up war-time production by direct dependence on commercial plants clinging closely to their own designs.

That distinction is reserved for a machine which is only indirectly military, for a craft which is used in substantially the same way in war and in peace, in the Navy, in the Army, and in civil life; for the airplane, in short, that is designed for training.

Many Planes for Training Will Be Needed

In case of our becoming involved in war, a 20-fold increase in the present training program of the Services would be an almost instant necessity. The number of training airplanes would perhaps need increase in an even larger ratio, for the conditions of war, with mechanics hastily mustered into the Service and with pilots rushed through to solo in the least possible time, are not the most favorable for long life of flying equipment. It may be expected that the opening of hostilities would find the Naval Service, and doubtless the Army Air Corps as well, although I do not venture to speak for them,

equipped with a number of Service machines sufficient to permit the placing in the air of the full strength of fully trained aviators. Under the conditions of a naval campaign, in which the wastage of aircraft is on the average far less rapid than that under such condition of land warfare as prevailed in France in 1917, existing airplane factories should be able to speed-up their output rapidly enough to keep pace with actual needs for active oversea service and with actual attrition during the first months of a war. Certainly in respect of that part of naval aviation which travels on carriers, the industry would be able to expand and increase production sufficiently to bring up the totals of Service equipment available as rapidly as shipyards could turn out carriers on which to base them. That aeronautical organization which is purely defensive, on the other hand, intended for scouting and patrol over the seas near American possessions, should make no great and early demands of expansion, for such defensive preparations should at all times in peace be kept up to the minimum strength necessary for efficient employment in war.

The great burden of increased production falls on the training program. In the event of war, the enrollment of men en masse would begin immediately, and their training as naval aviators would also have to begin at once so that they would be ready as soon as possible to use new Service airplanes, of which the production would be steadily accelerating, and only a few months thereafter to go to sea on new carriers.

Rapid Production of Training Planes Possible

Fortunately, we have ready to our hand the means of a considerable and rapid increase in training production if we prepare to make use of it. Reference has already been made to the astonishing growth of light commercial-airplane sales in recent months. The production of such airplanes for a commercial market is likely even now to outnumber the year's combined output of training airplanes for the Army and Navy. A leading manufacturer of engines for all markets estimates that within a year or two at most his commercial sales will be more than 50 per cent of the combined total of sales in all markets.

These light two and three-seaters are by no means the naval ideal of a training airplane, but that they are usable for that purpose their daily employment in many civilian flying-schools attests. Under war conditions they would be used in the Service on a grand scale, not exactly in their original form, but with only such modifications in design and structure as might be indispensable for reasonable efficiency in their new role. Their acquisition and use to the extent of the greatest possible production of the factories in which they had originated would be a necessity, to be accompanied by preparations for the building of increasing numbers of those machines designed specifically and exclusively for the particular purposes of naval training.

Standardization of equipment in the training school, as well as in the field, is highly desirable for utmost efficiency, but unstandardized equipment is preferable to none, and the builders of the small open-cockpit machines destined for private owners and for miscellaneous small commercial activities would be an indispensable adjunct while standardizing projects were being set in motion, factories were being turned over to new production, and new factories were being launched. The usefulness of these builders, however, would depend precisely upon the absence of any attempt to force adherence to a standard design or a standard method in their case.

Builders Should Plan for Conversion

There are today in the United States airplane factories that never have built a military airplane or sold a machine of any kind for military or naval purposes but which possess, in the aggregate, the capacity to turn out within 4 months, at a conservative estimate, 500 airplanes suitable for a considerable range of training activities, provided they are given dispensation to cling to their standard designs with such few changes in structure and installation as may be necessary to fit the intended purpose and to ease the transition of the pilot to the next type of airplane that he will encounter in his progress toward full qualification. If these factories were given the task of abandoning their standard designs and starting to build an ideal training machine previously developed by one of the regular Service contractors, there is room for considerable doubt on what the output of the first 4 months would be, but it seems safe to guess that actual production would fall closer to 100 than to 500.

The Service would want to make use of such standard machines in emergency, but the feasibility of doing so effectively would depend upon the exercise of some forethought by their constructors in time of peace. Every American builder of commercial airplanes ought to give some consideration to his own place in that scheme of industrial preparedness to which allusion has been made. As a patriotic citizen, each should feel it his obligation and his privilege to give consideration to the ways whereby his special qualifications, his plant, and his possessions could best contribute to the common defense. As the most obvious step in effective preparation for such a contribution, each constructor should reflect, under the calm conditions of peace, upon the means whereby his product could be adapted to serve a military end. Each ought to avail himself of opportunity for conference with officers of the Navy or the Army, to secure information upon the indispensable requirements of the military and naval Services, in training or wherever the prospect of ready conversion of any product may seem brightest, and to lay his plans for making his own product meet those minimum demands with the least possible delay or shock to his producing organization.

Word and Action

AN ancient and accredited adage says that actions speak louder than words, but I doubt it, for signs accumulate that modern mankind follows the talker rather than the doer. We are a word-ridden people. We worship words. We give our votes to words. We accept words as a substitute for works.

This is why it is important for us to overhaul our vocabularies periodically. Words that are used in controversies should be given a vacation when the controversies are over; otherwise they poison our spirits and pervert our thinking; they carry the meanings and misunderstandings of the old controversies over into new discussions. It is a hard task to keep language close to living reality, but the soundness of our civilization depends upon it.—Glenn Frank in *Class.*

The Wright Whirlwind Engine in Commercial Operation

By C. H. BIDDLECOMBE[1]

AERONAUTIC MEETING PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

EXPERIENCE obtained with the Wright Whirlwind engine in the 13 months of flying operation from June 18, 1926, to July 31, 1927, over the Boston-and-New York City Air Mail route is described. This period represents a total aircraft-flying time of 2146 hr. 35 min., or about 193,000 air-miles. Of the total flying-time, a three-engined Fokker airplane was used for 293 hr. 25 min., and during the remainder single-engined craft were used. The total engine-hours, therefore, was 2733 hr. 25 min.

Following a brief description of the three types of airplane used; namely, the Curtiss Lark, the Fokker Universal and Fokker Trimotor, all fitted with the Wright J-4B engine; this engine is described.

Special emphasis is placed on the cylinder construction, which is the outstanding feature of the engine, as the commercial success of the engine is said to be largely due to the remarkably efficient cooling obtained with this design of cylinder.

The inspection and maintenance system devised by the author is then taken up in detail, with an explanation of two of the forms in use: an "engine log-book sheet" and an "inspection card." The overhauling work required on the engine subsequently to a long period of running time is listed in detail; and a few cases of engine failure are fully described. Two tables, one showing the "Hours between Overhaul" of a group of 17 engines, the second giving data regarding 7 other engines, are appended. Parts of these tables consist of extracts from the records of two other Air Mail contractors and are reproduced through the courtesy of the Wright Aeronautical Corporation.

A brief comparison is made of the air-cooled and the water-cooled types of engine in commercial service, based upon the author's experience with both types, and comment is made on the advantages and disadvantages of three-engined aircraft for purely commercial operation.

ALTHOUGH I have been in the business of aviation for many years, I must confess to a certain diffidence in presenting this paper, as my knowledge of the Wright engine is limited to about 15 months of practical use of the engine; and this knowledge is still very incomplete. However, I purpose to present a little of the experience gained during the last year or so, in the day-to-day operation of the Air Mail route between Boston and New York City, from what may be termed the semi-technical executive point of view, as distinct from that of the highly technical engineer.

FIG. 1—THE CURTISS LARK

This Airplane Is of the Open-Cockpit Type and Is Designed To Carry about 600 Lb. of Pay-Load, Including Two Passengers Seated in a Separate Compartment Forward of the Pilot

The flying operations to be described cover the period from June 18, 1926, to July 31, 1927. In June, 1926, preliminary flying was begun between the Boston airport and Hadley Field, New Brunswick, N. J., in preparation for the opening of the Boston-to-New York City Air Mail route. Numerous flights were first made to enable the pilots to become familiar with the route and the equipment, and the service was formally opened on July 1, 1926. The route, as flown via Hartford, Conn., is about 220 miles in length, one flight and return being made each week-day. In addition, special flights, including sightseeing trips over New York City and Boston, are made on all days of the week.

THREE TYPES OF AIRCRAFT EMPLOYED

All the aircraft used were fitted with the Wright J-4B Whirlwind engine, and comprised one Curtiss Lark, two Fokker Universals and, for a few months, one Fokker Trimotor. The Curtiss Lark, shown in Fig. 1, is of the open-cockpit type, and was designed to carry about 600 lb. of pay-load, including two passengers seated in a separate compartment forward of the pilot. The Universals, one of which is shown in Fig. 2, are enclosed-cabin monoplanes carrying four passengers, or 800 lb. of mail or freight, the pilot being out in front of the wing immediately behind the engine. The Fokker Trimotor, Fig. 3, has seats for two pilots in an enclosed cockpit and chairs for 8 or 10 passengers in a large cabin, and is provided with three engines. With this equipment, a total aircraft-flying time of 2146 hr. 35 min. was completed between June 18, 1926, and July 31, 1927; of this total time, 293 hr. 25 min. was done by the three-engined craft, thus making a total engine-time of 2733 hr. 25 min. The flying covered about 193,000 miles, most of which was done across country in all weather by day and by night. No serious accidents occurred to passengers, pilots, mail or freight, although in March the Lark and one Universal, together with two engines and sundry spares,

[1] Aeronautical transportation engineer, New York City.

FIG. 2—THE FOKKER UNIVERSAL

Enclosed-Cabin Monoplanes of This Type Carry Four Passengers, or 800 Lb. of Mail or Freight. The Pilot's Position Is in Front of the Wing and Immediately Behind the Engine

were destroyed by fire in a hangar at Hadley Field. These two ships were later replaced with one Universal.

DESCRIPTION OF THE ENGINE

The Whirlwind engine, front and rear views of which are shown in Fig. 4, is of the air-cooled radial type. It has nine cylinders equally spaced around a central crankcase and fixed with a revolving crankshaft having but one throw. The master-rod attached to this shaft is in the vertical cylinder, the remaining eight connecting-rods being fastened to the crankshaft end of the master-rod by link-pins. The entire connecting-rod and crankshaft system revolves as a unit, and the firing-order is progressively in the direction of the propeller rotation on alternate cylinders, thus: 1, 3, 5, 7, 9, 2, 4, 6, 8. There are nine firing strokes for each two revolutions of the crankshaft. Ignition is by two independent magnetos, each firing one spark-plug in each cylinder. The engine will run on one magneto with a very slight loss of speed.

Lubrication is provided by a pressure-pump that carries oil into the rear end of the hollow crankshaft, from which point it is distributed under pressure to all the bearings. The excess of oil running through to the front end of the crankshaft is collected there and is returned to the rear of the crankcase by a suction-pump. A second suction-pump carries this returned oil from the rear of the crankcase to the oil-tank, the oil meanwhile passing through an oil-strainer where any foreign matter picked up in the engine is removed. The only two parts of the engine not lubricated under pressure are the cylinder-walls and the wristpins. These are lubricated by a limited amount of oil that is allowed to fly out of the crankshaft in the form of a spray within the crankcase. The oil used for lubricating the cylinder is that burned by the engine. The remaining oil is used over and over through the complete circulation system made up of the oil-storage tank and the engine itself. The carbureter is really three carbureters contained in one assembly, each of the three feeding three cylinders.

CONSTRUCTION OF THE EFFICIENT CYLINDER

As the outstanding success of the Whirlwind engine is due largely to the very efficient cylinder construction, this merits a detailed description. The cylinder, shown in a cross-section of Fig. 5, consists of an aluminum-alloy head and jacket with the cooling-fins cast integrally, screwed and shrunk upon a forged-steel barrel. The upper portion of the steel barrel is threaded for 1.25 in., the lower end being flanged and drilled for eight studs to secure the cylinder to the crankcase. Valve-seats are made of extruded aluminum-bronze shrunk and rolled into the cylinder-head. This valve-seat material has approximately the same coefficient of expansion as the aluminum head, has high heat-conductivity, and, under the hammering action of the valves, acquires a hard, polished surface that resists pitting and the erosive action of the hot gases. Each cylinder has one inlet and one exhaust-valve, each inclined at an angle of 8¾ deg. from the vertical and actuated by the conventional rocker-arm and push-rod.

Arranging the spark-plugs diametrically opposite each other in the side of the head has been found to reduce the operating temperature of the spark-plug and to assure uniform flame-propagation in the combustion-chamber. The number of fins and the fin area, both on the barrel jacket and around the exhaust-valve port, are the result of careful experiments directed toward obtaining efficient cooling. The inlet and exhaust ports are placed so that an air-stream can flow between them.

The net result of this design is a cylinder that maintains a working temperature that affords high power-output and low specific fuel-consumption. The dynamometer tests on a group of 15 engines have been averaged on the curves shown in Fig. 6. These curves form an interesting study of power output and fuel consumption.

The system of inspection and maintenance was based, first, on the recommendations of the Wright Aeronautical Corporation and, secondly, on wide general experience with internal-combustion engines. To avoid guesswork and haphazard methods, a set of printed orders was issued to all pilots and mechanics under the general head-

FIG. 3—THE FOKKER TRIMOTOR AIRPLANE

Seats Are Provided for Two Pilots in an Enclosed Cockpit and also Chairs for 8 or 10 Passengers in a Large Cabin. As Its Name Indicates, the Airplane Is Equipped with Three Engines

ing, Operation Orders, these orders covering practically all the points necessary for conducting operations. Only a few paragraphs from them will be summarized.

The section dealing with engines calls for a daily inspection of all engines in service; that is, at least once every 24 hr. This inspection was carried out regardless of the number of hours the engine may have been used since the last inspection; in addition, the engine, or engines, of every airplane arriving at a terminal airport, either at Boston or at Hadley Field, was normally inspected before the craft left the port on the next flight. Owing to the schedule of operations, this resulted in a thorough inspection after about every 3 hr. of flying, each engine being serviced at Boston and at Hadley Field

It will be seen that attention is paid to all valve-gears, magnetos, spark-plugs, carbureters and gasoline feed-lines, as these accessory features are, in general, the only items on the Wright engine that require attention. By this I mean that an average Whirlwind engine that is supplied with gasoline and oil will run perfectly for hundreds of hours without the least attention to its major components; namely, the cylinders, pistons, connecting-rods, oil-pumps, and the like; and that the advisability of careful, frequent inspection is due to the accessories and installation items.

In following through the inspection detail laid down, the mechanic checks each item and retains the signed cards for periodical checking-up and destruction by the

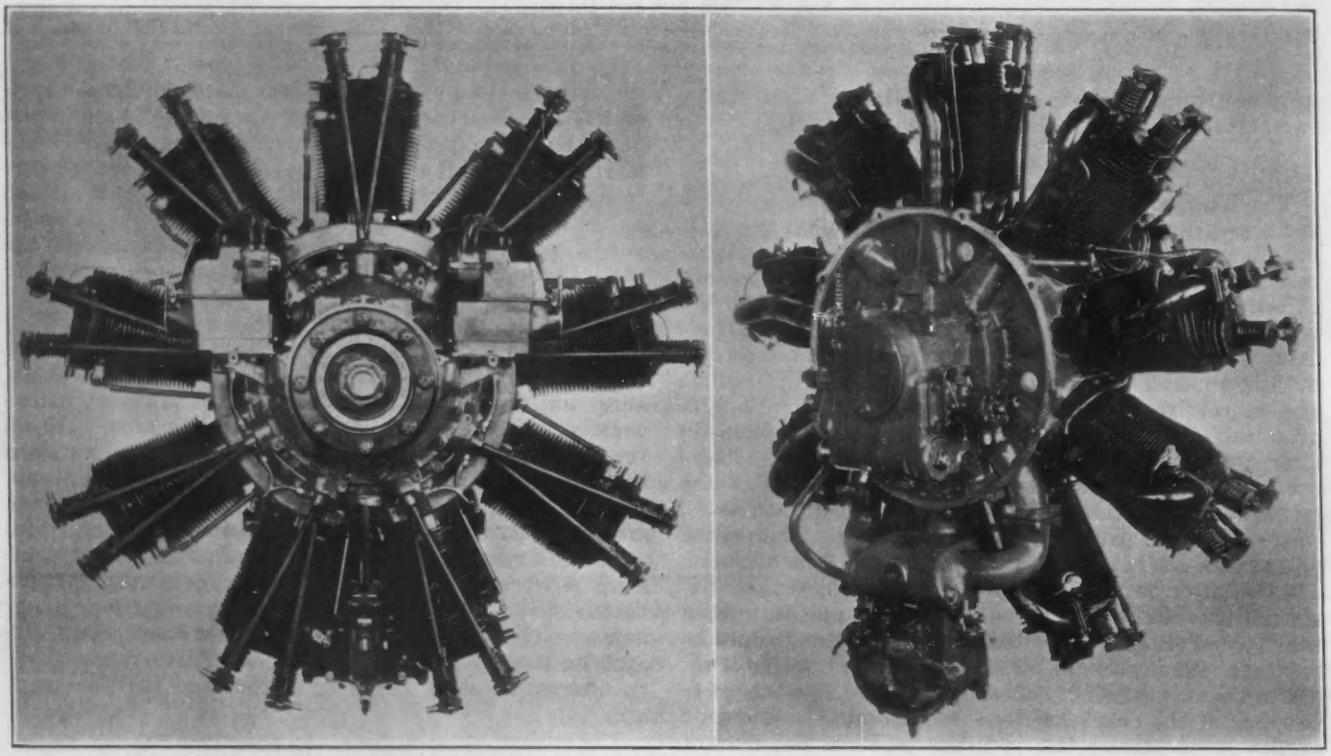


FIG. 4—FRONT VIEW (LEFT) AND REAR VIEW (RIGHT) OF THE WRIGHT MODEL J-4B WHIRLWIND ENGINE
This Engine Was Used in All Three of the Airplanes Illustrated in Figs. 1, 2 and 3. It Is of the Air-Cooled Radial Type and Has Nine Cylinders Equally Spaced around a Central Crankshaft. The Cylinders Are Fixed with a Revolving Crankshaft Having but One Throw. The Entire Connecting-Rod and Crankshaft System Revolves as a Unit

on alternate days. During the first 10 months of normal operation, this resulted in a remarkable freedom from mechanical irregularities, as might be expected; it was not, of course, an economically correct method of employing airplane equipment, which should be used to the utmost extent to justify the initial cost. In emergencies and, at a later date, when the flying equipment was used more intensively, the intervals between inspections were governed more by the flying-time factor than by the absolute time elapsed, and a maximum of 10 flying-hours was laid down as the period between inspections, in addition to the rule calling for an inspection at least once every 24 hr.

INSPECTION CARD AND ENGINE LOG-BOOK

The inspection and servicing work required consisted of the schedule contained on a printed card, reproduced in Fig 7, which was regarded as a spur to the memory of the mechanic performing the work, and not as a definite limit of the work that was to be performed.

manager of operations. As stated previously, the chief value of these cards is in preventing certain items from being overlooked during the inspection of the engine; the reverse side of the card covers the airplane inspection.

In addition to the inspection form-card, a permanent record of inspections and of all work done on an engine is recorded in ink in the engine log-book, one such book being provided for each engine. Instructions for use are contained in each book, and provide for a very complete record of the history of the engine. These are reprinted herewith. Typical sheets from a log-book are shown in Figs. 8 and 9. On one side, Fig. 8, are data concerning the engine before flight, during flight, and on arrival at the terminal; the other side, Fig. 9, contains a record of the servicing work done on a particular occasion. These sheets are of sufficient size to allow even the most flowing handwriting to be used.

In addition to the routine inspection outlined on the inspection form-card, a more thorough inspection is

scheduled after every 15 hr. of running-time; this includes the removing and cleaning of the gasoline, oil, and carbureter strainers; the removing, cleaning and adjusting of the spark-plugs; the very careful inspecting of magnetos; and the replacing of the used oil with fresh lubricant.

Lubrication of Special Importance

Careful attention to the details of these inspections is well repaid by an absence of trouble during flight; for instance, the regular oiling and greasing of the overhead valve-gear, rocker-arm pivots, push-rod sockets and rocker rollers contribute largely to the prevention of valve-gear lubricating-troubles throughout the whole operating-period Similarly, the careful cleaning of the main oil-screen every 15 hr. assures that very few internal lubrication troubles will occur.

In this connection I would express the opinion that oil-pressure gages are by no means entirely reliable guides as to what is happening inside the engine. In a number of engine designs it is possible to have a normal pressure-reading with a very restricted oil-flow, due to either a screen or a pipe-line that has been partly clogged with dirt or carbon. The result is frequently a frozen bearing with a uselessly short warning from the thermometer. An oil flow-meter, indicating circulation instead of pressure, would be of considerable value to the aeronautic engine, as such an instrument would indicate a falling-off in the oil-flow long before the pressure and temperature gages would do so.

The type of lubricant used in the Wright engine is of the utmost importance. This engine, like all air-cooled units of considerable power, is much more exacting in its demands on the lubricant than is the usual water-cooled engine. Although a number of good oils that can be used without danger of serious trouble are on the market, a few are exceptionally good. Two well-known brands were used in our operations, and the very light carbon-formation and the absence of gummy deposit on engines that had been run for more than 300 hr. fully justified the care taken in selecting them.

Suitable Fuel and Mixture Essential

It is also essential to use suitable fuel in the Wright engine; if low-grade commercial gasoline is used, the results probably will be disastrous. Preignition, detonation, overheating and the collapse of piston-heads

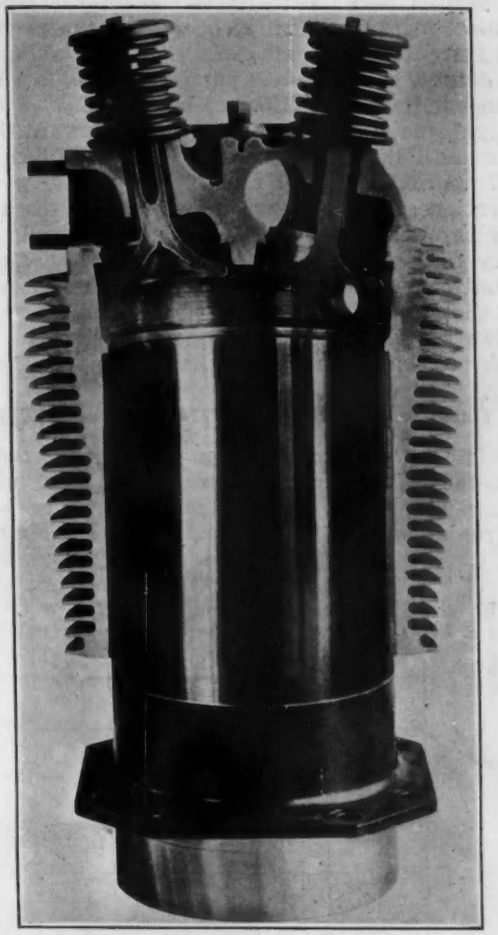


Fig. 5—Cross-Section of Whirlwind Engine Cylinder

The Cylinder Consists of an Aluminum-Alloy Head and Jacket with the Cooling-Fins Cast Integrally, Screwed and Shrunk upon a Forged-Steel Barrel, the Upper Portion of Which Is Threaded for 1.25 In., the Lower End Being Flanged and Drilled for Eight Studs To Secure the Cylinder to the Crankcase. Each Cylinder Has One Inlet and One Exhaust Valve, Each Inclined at an Angle of 8¾ Deg. from the Vertical and Actuated by the Conventional Rocker-Arm and Push-Rod

usually follow any attempt to use a fuel of poor quality.

A lean mixture for the engine should be avoided in summer temperatures. The carburetion-mixture control that is fitted can be employed usefully at altitude during cold weather, but I have found that, in the summer, it is unwise to attempt to obtain economy in fuel consumption by running engines on a very lean mixture. Overheating and loss of power were the penalties for allowing too great a proportion of air in the combustion-head.

I obtained some interesting figures showing the effect on brake horsepower and specific fuel-consumption when

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Instructions for the Use of This Log-Book

1—This Engine Log-Book must ALWAYS accompany the engine to which it refers.

2—When the engine is on service the columns must be filled in by the Pilot or Mechanic detailed to the aircraft.

3—Before departure on a journey the Pilot is PERSONALLY to ascertain that the statements entered in the Log-Book are correct and is then to sign the certificate.

4—When gasoline or oil tanks are refilled at a terminal airport, a Chief Mechanic or Foreman Mechanic is to be personally responsible for the operation, and is to sign the certificate to that effect.

5—All overhaul replacement or repair work carried out on an engine at a terminal airport is to be checked by a Chief or Foreman Mechanic and signed as instructed.

6—In cases of refilling, adjustments, etc., EN ROUTE, the Pilot is to be responsible and to sign the certificate.

7—The "Pilot's Report" and "Arrival" columns are to be filled in and signed immediately on the completion of journey.

8—The Pilot is responsible for the carriage of the Log-Book in the aircraft on a journey, and is to deliver it to a Chief or Foreman Mechanic on arrival at the terminal airport.

9—On test flights, the Pilot is responsible for filling in the "Time in Air" of the engine.

10—Any omission to record in this Log-Book any pertinent facts relating to the engine, particularly replacements and repairs, will be regarded as a serious neglect of duty.

the mixture-control was used on an engine running at 1800 r.p.m. This test was conducted on engine No. 6771, one of our stock, on an electric dynamometer with high-test domestic aviation-gasoline and with a commercial premium-fuel containing tetraethyl lead. The results are shown by the curves in Fig. 10. It will be observed that, as the mixture becomes leaner, or the specific fuel-consumption is decreased as is indicated by following all the curves from right to left, the horsepower increases to the maximum, then diminishes, and, when the mixture has become very lean, falls off rapidly. At the last-mentioned point the decrease in power is so appreciable that the specific fuel-consumption itself begins to rise and the curve doubles back; hence it is evident that the most economical point at which to operate is the position of the mixture control that gives a slight falling-off in power output, which, in this particular case, is a specific fuel-consumption of 0.50 lb. per b.hp.-hr.

In flight, the pilot adjusts the mixture toward the lean position until the engine revolutions by the tachometer fall off approximately 20 r.p.m. The engine will then be operating at its best economy so long as the altitude and the throttle-setting remain constant. Should a contingency requiring the maximum power arise, the mixture control should be moved to the full-rich position before the throttle is opened wide. Needless to state, it is always advisable to move the mixture control to the full-rich position before landing, as well as on the take-off.

Cylinder Runs Cooler with Rich Mixture

It is interesting to observe the effect on the temperature of the cylinder-head of leaning the fuel mixture. With a rich mixture, the cylinder runs cooler because of the rapid combustion, and possibly of the absorption

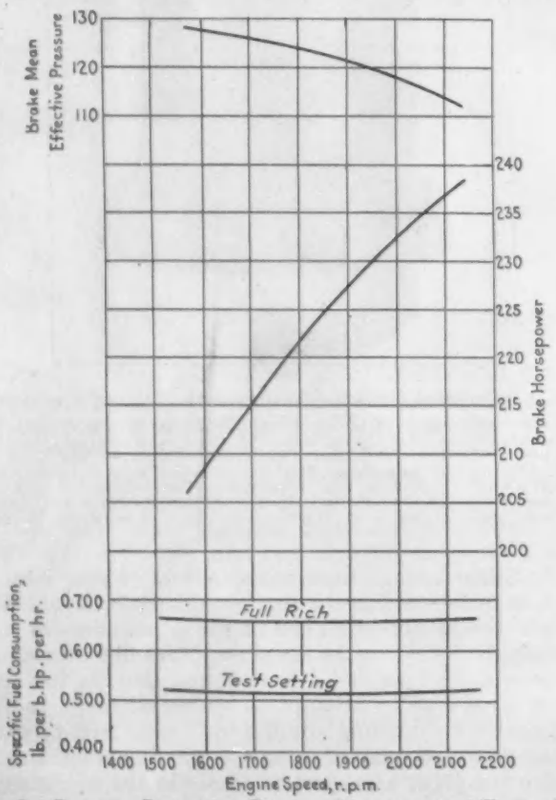

Fig. 6—Curves Showing Power Output and Fuel Consumption of the Wright Model J-4B Whirlwind Engine
These Curves Are the Average of Tests Made of 15 Engines. Aviation Gasoline Was Used

ENGINE
DAILY INSPECTION CARD

PORT ENGINE	CENTER ENGINE	STARBOARD ENGINE
Type Number	Type Number	Type Number
Engine-bearer Bolts		
OIL PIPES		
THROTTLE CONTROL		
MIXTURE CONTROL		
CARBURETOR		
IGNITION WIRING		
AND SWITCHES		
ALL CYLINDERS		
Cylinder Bolts		
Valve Clearances		
Rockers and Lock Wires		
Rocker Rollers and Locks		
Valve Springs and Locks		
Rocker Support Locks		
Rocker Rollers Oiled		
Rocker Shafts Greased		
Sockets Greased		
Push Rods Greased		
Spark Plugs		
H. T. Leads		
ENGINE INSTRUMENTS		

Certified Correct:
Pilot or Mechanic

Fig. 7—Daily Inspection Card Showing the Inspection and Servicing Work Required
The Schedule Given Is Regarded as a Spur to the Memory of the Mechanic and Not as a Definite Limit of the Work That Is To Be Performed

of heat in the evaporation of fuel particles within the cylinder. As the ratio of fuel to air is decreased, the mixture burns more slowly, a greater amount of heat is delivered to the cylinder-walls, and the tendency toward detonation increases, with the resultant rise in temperatures. As the mixture is leaned more and more, a point is reached, corresponding to that at which the horsepower falls off rapidly, where the weight of fuel burned is insufficient to maintain the cylinder temperature, and the curve doubles back as illustrated in the two lower curves of Fig. 10.

The effect of tetraethyl lead in suppressing detonation and in lowering cylinder temperatures is evident in the lower curve, which shows the results obtained with treated gasoline. The reduced power-output with this fuel may possibly be attributed to the poorer distribution resulting from the use of a gasoline with a high end-point and high specific gravity.

As stated, the mixture control was not used in the summer operations, and, as a further precaution against overheating, the fuel used consisted of 75 per cent of gasoline and 25 per cent of benzol. The benzol content produces an effect similar to tetraethyl lead in preventing detonation and keeping the cylinder-heads cool, but no falling off of power occurs with this mixture. I have used benzol for this purpose for the last 10 years. Provided the sulphur content is low, the results undoubtedly are beneficial. It is essential to obtain a benzol of the highest possible purity, for corrosion is caused by the presence of sulphur; in addition, benzol cannot normally be used in sub-zero temperatures, owing to the fact that it separates and freezes after it has been mixed with the gasoline.

Gasoline and Oil Specifications

Brief specifications of the gasoline and oil used are as follows. It will be noted that provision is made for use of a heavier oil in the summer months, but, in practice, the same oil was found satisfactory throughout the year. The object of using an oil with a viscosity of more than 100 in the summer was purely economical. The lubricating qualities of the winter oil are not

JOURNEY FROM *Flights at Teterboro* TO Date *5-30-27*

DEPARTURE			ARRIVAL		
PLACE	TIME	REMARKS	PLACE	TIME	REMARKS
Teterboro	*10:00 a. m.*		*Teterboro*	*7:30 p. m.*	

Engine R. P. M.	*1600*	Engine R. P. M.	*1800*
Oil pressure □ in.	*50*	Oil pressure □ in.	*50*
Oil temperature	*70*	Oil temperature	*105*
Oil in tank	*O. K.*	Oil in tank	*O. K.*
Fuel pressure □ in.	——	Fuel pressure □ in.	——
Fuel in tank	*O. K.*	Fuel in tank	——
Water temperature	——	Water temperature	——
Water in radiator	——	Water in radiator	——

Certified correct:

Mechanic .....

Pilot *L. H. T.*

Certified correct:

Mechanic .....

Pilot *L. H. T.*

PILOT'S REPORT

	PLACE	TIME	REMARKS
	Arr.		
	Dep.		
	Arr.		
	Dep.		
	Arr.		
	Dep.		
AVERAGE ON JOURNEY	R.P.M.	*Var.*	
	Oil pressure	*50*	
	Oil temperature	*105*	
	Fuel pressure	——	
	Water temperature	——	
	Air speed	*Var.*	

Pilot *L. H. Thomson*

ENGINE FLYING HOURS

	Hr.	Min.
TEST FLIGHTS	——	
SERVICE FLIGHTS	*6*	*00*
TOTAL		
BROUGHT FORWARD	*127*	*05*
TOTAL TO DATE	*133*	*05*

Chief Pilot *L. H. Thomson.*

FIG. 8—OBVERSE OF TYPICAL SHEET FROM THE LOG-BOOK
On This Side Are Shown Data Before Flight, During Flight and After Arrival at the Terminal

RECORD
OF
INSPECTIONS, OVERHAULS, REPLACEMENTS AND REPAIRS

PLACE *Teterboro* Date *5-31-27*

Washed down Motor. Tightened all Spark-Plugs. Drained Carbureter Wells. Checked Engine-Bearer Bolts and tightened one that was loose. Greased Push Rods, Sockets, and Rocker Rollers and Rocker Shafts. Checked Valve Clearances and all Valve and Rocker Assembly; also Ignition Wiring and Oil Pipes. Checked Cylinder Bolts, Manifold Nuts, etc. Oiled Valve Stems. Checked Throttle and Mixture Controls.

Chief Mechanic *L. Woody.*

INSPECTED:
SERIAL No.
TIME *11 a. m.*

PLACE DATE

INSPECTED:
SERIAL No.
TIME

Chief Mechanic .....

FIG. 9—REVERSE OF TYPICAL SHEET FROM THE LOG-BOOK
This Is the Reverse Side of the Sheet Shown in Fig. 8 and Is a Record of the Servicing Work Done on a Particular Occasion. The Sheets Are of Sufficient Size To Allow Even the Most Flowing Handwriting To Be Used

affected in the least by summer temperatures and, with the particular engines in use, it was found that the consumption actually did not increase appreciably.

Gasoline Specifications.—The gasoline shall be free from water and suspended matter. The color shall not be darker than No. 25 Saybolt. One hundred cubic centimeters of the gasoline shall cause no gray or black corrosion, and the amount of deposit when evaporated in a polished copper dish shall not exceed 3 mg.

Distillation Range	Deg. Fahr.
Initial Boiling-Point	95
53 per cent off	221
84 per cent off	284
96 per cent off	355
End Point	375

The residue shall show no acid reaction. The sulphur content shall not exceed 0.10 per cent.

Oil Specifications.—

Flash Point, deg. fahr.	435
Fire Point, deg. fahr.	495
Pour Point, deg. fahr.	35
Viscosity at 210 Deg. Fahr., Saybolt sec.	75
Carbon, per cent	0.92

For summer use, oil of heavier body will be required, the viscosity being between 100 and 125 at 210 deg. fahr.

Engine Overhauls Made at Wright Works

For several reasons it was decided to limit the mechanical staff to the barest possible minimum, and operations were conducted with two mechanics and one helper; this precluded the possibility of making overhauls either at Boston or at Hadley Field.

Engines were therefore sent to the Wright Aeronautical Corporation's works, a distance of 7 miles by road,

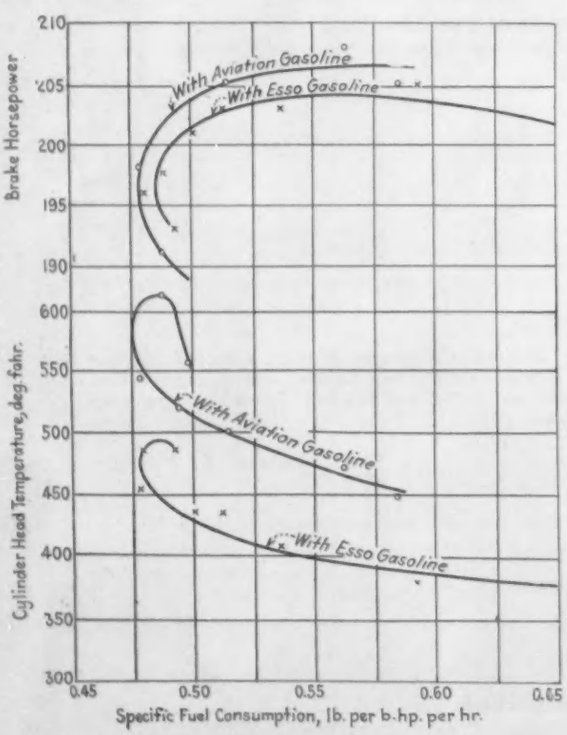

Fig. 10—Curves Showing Effect of Mixture Control on Brake Horsepower and Specific Fuel-Consumption

These Are from Tests Made on a Wright Model J-4B Engine Running at 1800 R.P.M. with Aviation Gasoline and with Esso Gasoline. The Temperature of the Air Was 90 Deg. Fahr.

Engine-Overhaul Record

Place, Paterson, N. J.	Date, February, 1927
Engine Type, J-4B	No. 6975
Total Hours, 331—50	Hours since overhaul, 331 hr. 50 min.
Name of Part	Details of Work
Crankcase	Remove nicks at cylinder location and polish ball-bearing retainer
Cam and Hub Assembly	Scrape and polish center bearing
Push-Rods	Repaint
Articulating-Rods	Scrape small end, Nos. 3, 7 and 8. Scrape large end, Nos. 2, 4, 6 and 9
Crankshaft	Polish journals and spacer
Master Rod	Scrape light score on small end
Pistons	Remove carbon. Scrape light score on skirt of No. 4 piston. Replace No. 7—cracked
Cylinders	Stone light score in bore No. 2. Recut valve-seats. Replace all valve-guides
Valves	Reface seats. Polish stems. Regrind in cylinders
Ignition Wires	Replace
Magnetos	Overhaul
Intake Manifold, Oil Sump and Carbureter	Disassemble, check float level and jet size. Clean strainers

for all repair work of a major nature. A typical engine-overhaul record, in which the work listed was all that was required to bring the engine back to "as new" condition, is shown herewith. The only replacements necessary after a running time of 331 hr. 50 min. were one piston and a set of valve-guides. The latter were good for at least an additional 100 hr. of running, but, as it was desired to obtain another 250 hr. without a second overhaul, the guides were replaced. The replacements on the engine during this 332 hr. were limited to four valve-springs and two sets of spark-plugs, at a cost of $13.64. This economy in replacement cost is a remarkable feature of the Wright engine.

Running Time and Operating Data

Tables 1 and 2 provide an interesting study of the results obtainable with this powerplant. Of the 24 engines listed in the tables, 7 were used on the Boston-New York City route and the others in service on two other mail routes. I am indebted to the Wright corporation for permission to use these figures, supplied by the owners of the engine.

The gasoline and oil-consumption figures compare closely with those published in connection with the recent transoceanic flights, when allowance is made for the difference in conditions, and are a useful comment on the somewhat general belief that an air-cooled engine is extravagant with fuel and oil. Similarly, the cost of replacement parts and repairs, $280.82, over a running time of 3530.5 hr. on seven engines, is also very low.

Causes of Engine Failures

Excluding failures of gasoline supply-lines, when no fault was traceable to the engine, three major failures occurred in the period under review. Two of these caused forced landings; the third was discovered on the ground. In one case, the cam-ring bearing froze, causing the complete stoppage of the engine; this particular

bearing was of "Y" metal in the J-4B engine, but has been replaced by babbitt metal in later models. The failure of the bearing was caused presumably by insufficient oil. This point is lubricated through a small hole in the hollow crankshaft, around which the bearing fits concentrically, the oil under pressure in the shaft being forced out through the hole. In case this hole is partly blocked by a foreign body, such as a minute piece of carbon, the resultant reduction in oil-flow will cause failure of the bearing. As the pressure remains unchanged, this will not be indicated on the oil-pressure gage until the moment of complete failure, and the warning from the oil-temperature gage is extremely brief. The obvious means of preventing such trouble is, of course, periodic and thoroughly cleaning of the oiling system. This should include the cleaning of the hollow crankshaft by removing the plug in the forward end at intervals of not more than 100-hr. running; the oiling system, including screens, will be cleaned at the time of changing the oil. When these precautions are taken, no difficulties should be experienced with cam-ring-bearing lubrication.

A second engine-failure that caused a landing was the breaking of an exhaust-valve rocker-support member on the No. 4 cylinder. The engine had done a total of 127 hr. 10 min. flying-time, and the aircraft with mail and four passengers was en route from Boston to New York City at night. The breaking of the rocker-support put No. 4 cylinder out of action, but the pilot made a safe landing at an emergency field at New Canaan, Conn., reaching the field on about 1100 r.p.m. of the engine. Subsequent examination of the broken member showed a flaw in the casting that probably existed as a minute crack when the part was new, as it was in the center of the piece of metal and undetectable by any method of inspection. This flaw extended through the line of maximum stress of the part under running conditions and eventually left an insufficient quantity of sound metal to carry the stresses. The engine ran perfectly again the next morning, after the rocker-arm and one push-rod had been replaced.

The third failure was the breaking of a piston just above the wristpin. This piston broke in two places, the head remaining at the top of its travel in the cylinder and the bottom continuing to move with the connecting-rod. The engine was being run on the ground at the time and the first indication of trouble was a falling-off of the speed. After the spark-plugs had been removed from the cold cylinder, the piston-head was observed to remain stationary when the engine was turned over by hand. This failure also probably was due to an internal flaw in the casting.

TABLE 1—RUNNING TIME OF 17 WHIRLWIND ENGINES

Engine No.	Total Time, Hr.	Min.	First Overhaul, Hr.	Min.	Second Overhaul, Hr.	Min.	Third Overhaul, Hr.	Min.
6955	366	57	366	57				
6962	403	25	301	10	Destroyed—Hanger Fire			
6964	351	25	277	14	Destroyed—Hanger Fire			
6965	753	16	302	30	401	55	567	48
6966	688	16	254	36	589	31		
6967	530	17	197	05	247	20		
6968	680	20	356	35	680	20		
6975	447	30	331	50				
6979	523	40	383	46				
6982	837	25	276	37	633	00		
6995	891	05	389	28	716	48		
7006	276	00	251	15				
7220	635	10	241	45	635	10		
7221	238	55						
7230	286	50	286	50				
7240	292	10	292	10				
7245	297	35	193	05				

Average time to first overhaul, 293 hr. 56 min.
Average time to second overhaul, 557 hr. 43 min.
The average for the second overhaul was obtained for seven engines only. The true average probably was higher.

TABLE 2—OPERATING DATA FOR SEVEN WHIRLWIND ENGINES

Engine No.	Total Time, Hr.	Min.	Engine No.	Total Time, Hr.	Min.
6999	329	55	7218	675	25
7215	540	35	7219	484	10
7216	640	20	7243	238	05
7217	622	05			
Grand Total	2132	55		1397	40

Total running time,	3530 hr. 35 min.
Cost of replacements,	$280.82
Cost of replacements per flying hr.,	$ 0.079
Average gasoline consumption per hr., gal.	11.5
Average oil consumption per hr., including changes, qt.	2.2

Some of the Minor Troubles Experienced

With these exceptions, no serious trouble was experienced with any of the engines during the 13 months of operation that have been reviewed. Minor troubles arose from time to time, such as moisture collecting in the distributor segments of the magnetos after a heavy rain and causing irregular firing of one or both banks of spark-plugs. This was easily cured by the application of vaseline, or by using a wax seal, or even chewing-gum in emergency, on the high-tension-lead outlets. Shielding the magnetos with a light metal hood of suitable design will also prevent this difficulty. Spark-plugs occasionally failed, but this was infrequent, as the cylinder-head temperatures are not normally high enough to shorten appreciably the usual life of a well-made plug.

Difficulty in starting in the early morning following freezing temperatures overnight caused some annoyance when aircraft were left in the open constantly and a particular make of spark-plug was used. A change in the type of spark-plug proved beneficial, as it was found that one design was persistently liable to collect moisture on the points, caused by condensation within the cylinder when a warm engine was exposed to frost all night. The type of spark-plug now used as standard has obviated this trouble and the plugs can, in many cases, be used for as long as 200 hr. before being discarded, provided they are periodically cleaned and set.

Carbureter heaters were found essential in the winter months; in the early summer operations, no heating device was employed, but, as the weather changed in late November, it was found impracticable to continue flying without these attachments. The heaters were retained throughout the summer of 1927 and are now a standard fitting on all engines.

Possible Reason for Ocean Flight Failures

Incidentally, some of the recent failures on transatlantic flights may possibly have been caused by the absence of an efficient carbureter-heating device on the engines used. The loss of Old Glory, with Bertraud, Hill and Payne, may have been due to the formation of ice in the carbureter while they were flying at a reasonably great altitude, and the same thing may have happened in the case of Princess Lowenstein-Wertheim, flying westward with Hamilton and Minchin. The air-cooled engine used on both these airplanes is not normally fitted with a carbureter heater.

This theory is supported by the experience of Maitland

and Hegenberger on their transpacific flight. It will be remembered that they reported partial engine failure while flying at about 10,000 ft., which, however, corrected itself while they were descending to a lesser and warmer altitude. In this case, I understand that the heaters were not fitted to the engine; and it seems probable that a forced descent was avoided only through the use of three engines, which gave a sufficient power-reserve to keep them in the air while the carbureters thawed out in a warmer atmosphere. With a single-engined craft, heavily loaded, a falling off in speed and power owing to the formation of ice would bring the airplane down to the water too rapidly for the carbureter to thaw out, according to our experience on the Boston-New York City route. This theory is, of course, only one of many that can be advanced to explain the losses in both the Atlantic and the Pacific flights. It is possible that overdriving of the engines caused some, and weather conditions the rest.

Air-Cooled and Water-Cooled Engines Compared

It probably will be of interest to touch on the main advantages of the air-cooled engine for commercial use. The principal gain is, obviously, the simplicity of air cooling, which eliminates a formidable list of trouble-causing details. With the water-cooling system, the chances of engine failures are appreciably increased. This is inevitable, as the presence of water-jackets, pipes, radiators, radiator shutters, pumps and hose-connections cannot but increase unreliability, when the airplane is concerned. Added to failures in the component parts of the system itself, there is also the question whether water cooling does not handicap the reliability of the other parts of the engine. For example, valve breakage and distortion have always been serious factors in the water-cooled engines with which I have had first-hand experience. I feel that the satisfactory cooling of valves can be obtained much more readily with air-cooled engines.

A careful study of 1 year's operation of two makes of water-cooled engine in Europe showed that, of the failures necessitating the removal of an engine from the airplane, 28 per cent were caused by the water system, and 19 per cent by bent or broken valves. These figures were definitely established and I believe that all the breakdowns they represent are traceable directly to the water-cooling principle. A further 20 per cent of the troubles experienced during this particular year were classified as miscellaneous or indefinite. Of this percentage, at least one-half probably were due to water cooling; so that, in my opinion, a total of 57 per cent of the failures were due directly or indirectly to water cooling. It may be noted that 23 per cent of the breakdowns during that year were due to breakages of material, 10 per cent to oiling trouble, and the remaining 10 per cent were indefinite.

Saving in Weight an Important Factor

The saving of weight with air cooling is another important factor, an average of about 0.6 lb. per hp. representing the weight of a water-cooled system installed ready for flight; this means an addition of about 120 lb. to the pay-load of an airplane with a 200-hp. air-cooled engine, as compared with a water-cooled engine of the same power. There is also an indirect saving in the structural weight of the airplane by the use of the lighter engine, amounting frequently to more than 50 per cent of the direct gain. In one extreme case that came to my notice recently, the replacement of a water-cooled engine by an air-cooled unit of slightly greater power resulted in a saving in weight of 500 lb.

The accessibility of the modern air-cooled radial engine is a further point in its favor; this is particularly so with the Wright Whirlwind, from which a cylinder can be removed in about 15 min. by experienced personnel. Similarly, the accessory fittings, including the magnetos, carbureter, spark-plugs and oil-pumps, can be adjusted more easily on this engine than on any water-cooled unit I have handled.

The use of a water-cooled engine in extremely cold weather and without adequately heated hangars has obvious drawbacks. The nuisance of draining the radiators at night and of providing hot water in the morning is not to be disregarded when running on a time schedule with aircraft; I do not suppose that anyone has ever calculated the number of pump vanes and spindles that have been sheared off by the ice that has formed on winter mornings.

In general, I think it has been established that the air-cooled engine is more reliable, more adaptable to extreme temperatures, easier to maintain and overhaul, lighter for a given power, and certainly more suited to economically correct airplane-operation than is the water-cooled type. Broadly speaking, I believe that the air-cooled engine is the foundation on which commercial aviation will be built; but when speed, and speed alone, is the requirement of an airplane, the water-cooled engine will undoubtedly hold its own.

Operation with Three-Engined Aircraft

As the operations covered in this paper include the use of three-engined aircraft on a regular schedule, I shall summarize the experience gained. First, it will be appreciated that a direct bald comparison between, say, the Leviathan and a Boston-New York City steamboat is not logically possible; each is designed for a specific purpose and for meeting a particular set of conditions, although both ships are propelled by steam power and carry passengers across a stretch of water.

In the same way, no direct comparison is of value in the case of single-engined and multi-engined aircraft; the basis of discussion, therefore, must be the purpose and conditions governing their use. With this distinction clear, it may be stated that the Boston-New York City mail-route is unsuitable for the operation of three-engined aircraft; the route is too short, the surface transport available is too well developed, and the mail-carrying schedule called for is unfavorable to the operation of a passenger service. The actual operation of a three-engined craft on this route was successful so far as mechanical reliability was concerned. Seventy single journeys were made, together with various special flights that totaled a flying time of 293 hr. 25 min., with no forced landings due to mechanical failure. Several hundred passengers were carried, principally on short sightseeing flights, and the performance of the craft was entirely satisfactory. From an economic point of view, however, the experiment was not successful, as the operating costs of this type of airplane are not justified by the small volume of traffic available over this route.

Conditions Adverse to Large Airplanes

It may be regarded as an axiom that, except under unusual conditions, air transport cannot at present compete successfully with rail and highway transport over distances of less than 600 miles. The reasons are fairly obvious: the airplane normally has one advantage, speed, and speed is effective only from airport to airport. Pas-

MULTIPLE AND SINGLE-ENGINED AIRPLANE OPERATING COSTS COMPARED

Operating Costs of a Trimotor Airplane

Investment	
Aircraft, complete with engines, instruments and equipment	$40,000
Interest on investment at 6 per cent per year, per month	200
Obsolescence	
The estimated life of the aircraft, on the obsolescence basis, may be accepted as 3 years, which gives a depreciation rate per year of	8,333
On this time basis, a salvage value of $500 each is allowed for the engines at the end of the 3-year period. The original cost may be assumed as $4,500 per engine, which gives an obsolescence depreciation of $13,500 less $1,500, or $12,000, or, per year,	4,000
The instruments and equipment, valued at $1,500, may also be assumed to bear obsolescence charges at the 3-year rate; that is, per year	500
Total obsolescence, per year	$12,833
Thus, the trimotor aircraft, when out of operation, carries the following standing charges per month, excluding storage, insurance and such maintenance as may be required	
Interest on capital, per month	$200
Obsolescence, per year, $12,833; or, per month	1,069
Total, per month	$1,269
With the craft now in operation, the above obsolescence charges do not apply, as the depreciation rate per flying-hour replaces the obsolescence factor	
Operating Costs	
Insurance, complete cover, $8,500 per year, per month	$708.30
The amount deductible is a flat rate of $1,000 in case of accidental damage. Assume one accident per year, costing the assured $1,000, per month	83.33
Flying Costs	
On mail schedule, hours per month	145
Casual sightseeing flights, hours per month	16
Total flying-hours, per month	161
Direct flying costs, including fuel and oil, engine and aircraft maintenance, pilots' flying pay for day and night flying, and additional labor costs directly chargeable to the aircraft, per month	$5,712.61
Indirect flying costs, including depreciation of aircraft and engines on a 3000-hr. and a 1000-hr. life, respectively, plus forced-landing expenses, per month	3,614.63
Summary	
Interest on investment, per month	$200.00
Insurance, per month	708.30
Deductible charge, per month	83.33
Direct flying-costs, per month	5,712.64
Indirect flying-costs, per month	3,614.63
Total operating cost, per month	$10,318.90
Flying-time, at an average speed of 95 m.p.h., hr.	161
Cost per mile, excluding overhead	$0.67
Overhead Costs	
Total, including salaries and wages, office and field costs, and the like, per month	$7,757.00
Cost per mile, including overhead	1.18

Operating Costs of a Single-Engined Airplane

Investment	
Aircraft, complete with engine, instruments and equipment	$13,500.00
Interest on investment at 6 per cent per year, per month	67.50
Obsolescence	
On a 3-year basis, the rate on the airplane per year is	2,666.00
Allowing a salvage value of $500 for the $4,500 engine at the end of 3 years, the annual obsolescence charge is	1,333.00
The instruments and equipment, valued at $1,000, may also be assumed to depreciate at the annual rate of $333. The single-engined airplane, when out of action, carries standing charges per month, excluding storage, insurance and maintenance, as follows:	
Interest on capital	$67.50
Obsolescence	361.00
Total for single-engined airplane	$428.50
Total for trimotor airplane	1,269.00
Difference	$840.50
With the airplane in operation, the obsolescence charges are replaced by an allowance for depreciation per flying-hour	
Operating Costs	
Insurance, complete cover, including passengers, per month	$416.66
Crash deductible, per month	83.33
Total, per month	$499.99
Flying Costs	
On the same basis of operation as those of the trimotor airplane	
Direct costs	$2,822
Indirect costs	1,390
Summary	
Interest on investment, per month	$67.50
Insurance, including deductible, per month	499.99
Direct flying-costs, per month	2,822.00
Indirect flying-costs, per month	1,390.00
Total operating cost, per month	$4,779.49
Flying time, at an average speed of 90 m.p.h., hr.	161
Cost per mile, excluding overhead	$0.33
Cost per mile, including overhead	0.87

sengers, freight or mails carried by air must be conveyed to and from the airports; and it is in this stage of the journey from city to city that so much time is lost that can be regained by the airplane only if the flying-distance is more than 600 miles.

In the case of the Boston-New York City route, the lack of a New York City airport, the small size of the Boston airport, and the inherent disadvantages of an absurdly short route rendered it impossible to operate trimotored aircraft at a profit.

The carrying of mail and express matter alone does not warrant the use of any but a single-engined craft on overland journeys and, in any case, the carrying of passengers at night should be avoided, except over a fully organized route. By limiting the traffic to mail and express matter, the Boston route ceases to be a separate entity and becomes an integral link of a much longer chain, the Transcontinental Airway. This makes it possible to reduce the overhead charges incidental to the

development of air passenger-transport business, to decrease the personnel, and to operate a type of aircraft that is economically suitable for the real purpose of the route, which is the connecting of New England with the transcontinental mail-service.

Comparison of Operating Costs

The question of the operating costs of trimotor aircraft compared with those of single-engined craft has been the subject of much discussion in recent months, and a study of the costs applicable to a definite route may provide material for further discussion.

Incidentally, it should be explained that the conclusions to be drawn from the costs tabulated relate only to one particular route that is operated in a manner governed by the mail schedule. To put it more clearly, the cost per mile, $1.18, for the trimotor craft, including overhead, is based on a certain overhead and a certain mileage; if this overhead and mileage are varied, as they would be on an entirely different route with an entirely different organization, the per-mile cost will vary correspondingly.

An analysis of the accompanying cost figures shows that the operating cost of the trimotor airplane is more than double that of the single-engined craft, while the cost to be met when the ship is idle for repairs or overhauling is nearly three times as great. This second factor is of importance, as, in practice, the presence of three engines obviously causes a greater total period of idleness during a year's operation than does that of one engine; it is impracticable, unfortunately, to synchronize exactly the days on which all three engines shall be withdrawn from service for overhauling or kept on the ground for minor adjustments.

Multi-Engined Plane a Vehicle for the Future

Turning to the earning capacity of the two types of airplane, it was found that, on this particular route, the trimotor airplane was able to earn only about 33 per cent more than the single-engined plane; it was therefore uneconomical to continue the use of large aircraft under these circumstances. Incidentally, I should like again to emphasize that these figures refer only to a specific route; under different circumstances the multi-engined plane might be found highly profitable. For example, over a route on which a large volume of passenger traffic can be built up because of poor surface-competition, or when a forced landing means certain disaster, the multi-engined airplane, from every point of view, is undoubtedly the correct vehicle to use.

In general, however, I would hazard the opinion that the economically correct method of developing air transport in the next 2 or 3 years lies in the use of single-engined airplanes with a pay-load of from four to six passengers, or from 800 to 1200 lb. of freight, the pay-load being at least 4 lb. per hp. The large multi-engined plane is without doubt the vehicle of the future, but, to obtain full efficiency with this type, it is necessary to have highly developed traffic and a completely organized route; and both these factors at present exist in only a few cases.

In conclusion, I wish to express the very sincere opinion that the whole aircraft-operating industry owes a great deal to the courage and vision of the men who have made the air-cooled engine possible. The reliability and economy to be obtained from the Wright Whirlwind engine is an increasingly important factor in commercial aviation. To those responsible for the engine, Charles L. Lawrence and the Wright Aeronautical Corporation, together with Commander Wilson and Lieutenant-Commanders Mullinix and Champion, of the Navy, is due the highest credit for their achievement. It is to the steadily and persistently constructive efforts of men of this type that America owes her world supremacy in unsubsidized and genuine commerce of the air.

Price and Sales Volume Interdependent

AN excess of productive capacity is a normal condition for a progressive country such as ours. It is the result of continuous improvement in the art of manufacture. New and more efficient facilities are created which replace antiquated facilities. Meanwhile, there is an apparent excess of productive capacity, but much of this is merely nominal, as it is represented by facilities which it is no longer economical to use.

The continual pressure of the more modern and efficient producers to take business away from their less progressive competitors I regard as entirely healthy in its general operation. It is through such competition that the American public has been progressively supplied with better and cheaper merchandise and American industry has been stimulated to such a point of efficiency that it is now the envy and wonder of the world.

From the bankers' standpoint it emphasizes the importance of conservatism in industrial accounting and financing and the necessity for making adequate reserve provisions against depreciation and obsolescence of plant and facilities, and for the expenditure by industries of adequate amounts for the development of their product and facilities. Industries whose managements observe these precautions develop in step with the Country. Those who fail to do so ultimately find themselves on the scrap heap.

The decline in general commodity prices will probably continue for a long time. The fact that this phenomenon has taken place with the accumulation of gold and the expansion of credit facilities may be unprecedented, but it is a fact. It has reacted adversely more or less directly upon farm products and mining; but, for the preponderant part of our industry which is engaged in the conversion of various raw materials and commodities into more highly refined products, the adverse effect of declining commodity prices upon such conservative inventories as have been carried appears to have been more or less offset by the broadening of their markets made possible by lower prices based upon the lower commodity price levels that have prevailed recently.

No doubt economies in distribution can be effected by more efficient methods which will narrow the margin now necessary to maintain middlemen, and such economies will still further broaden markets. The automobile business, above all others, has demonstrated the intimate interdependence between price and volume, and when it comes to affecting the breadth of a market it appears that economies in distribution will be just as effective as economies in production.

Opinions along this line, however, must be highly qualified because there is no denying that volume production has been made possible in many lines only by broadening the markets through the stimulation of intensive sales effort and advertising. Advertising and intensified sales methods are expensive, and it will continue to be a problem for managements to decide whether the expense so incurred is productive of sufficient increase in volume of business to show a net increase in the profits of the operation considered as a whole.
—Walter P. Chrysler, in a symposium on Distribution, published by the Farmers' Loan & Trust Co.

FIG. 1—PN-10 FLYING BOAT, ASSEMBLED IN SKELETON FORM
Construction Details of This Plane Are Shown in Figs. 4 and 8

Metal Construction of Aircraft

By COMMANDER R. D. WEYERBACHER, U. S. N.[1]

AERONAUTIC MEETING PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

The author enumerates the limitations of wood and the advantages of metal as structural materials for aircraft and concludes that weight can be saved and greater reliability secured with metal construction. The savings effected by the use of metal in place of wood in a Navy flying-boat are tabulated and commented on.

The use of metal, chiefly aluminum alloys, for fittings and structural parts is outlined and illustrated in detail, and an interesting expedient for the production of pressed-metal parts in small quantities is described. Details of the fabrication of ribs, fuselages, hulls and floats are given.

Emphasis is laid on the necessity for preventing corrosion by avoiding contact between dissimilar metals and by thorough application of protective coatings to both interior and faying surfaces.

BECAUSE of the popular interest displayed in aviation and the corresponding progress achieved during the present year, aircraft constructors have been able to turn to metal as the structural material that is most satisfactory, although initially more costly.

Wooden structures readily change in shape and size through swelling and warping when subjected to the influence of heat and moisture. It is therefore necessary continually to reset and true up a plane fabricated from wood. Wood is subject to rot and decay. It warps and twists and splits as a result of temperature and humidity changes. It is attacked by insects. It multiplies the dangers of fire.

The working of wood has distinct limitations, while metal can be given almost any form by pressing, rolling, drawing, extruding, forging and casting. In addition, metal is just as workable as wood by turning, milling, planing, drilling, filing, boring and punching. Joints and connections in wood are restricted to those made by gluing, bolting, mortising, and wrapping with fabric, all of which are of limited dependability. The types of joint possible with metal are more reliable and varied, including riveted, bolted, folded, welded, brazed and soldered joints.

The strength of metal is constant and can be determined in a reliable manner by test; wood is not homogeneous and different specimens of the same species of wood show great variation in strength. This requires the use of a higher factor of safety in wood fabrication than in metal for the same degree of assurance.

WEIGHT CAN BE SAVED WITH METAL

Weight is the greatest single factor in the use of metal rather than wood. In the first applications of metal to aircraft construction, when exact duplication in metal of the form of the wooden structure was attempted, the weight saving was not so appreciable. New materials require new design technique, which is developed gradually. At present it is reasonable to ex-

[1] Construction Corps; manager, Naval Aircraft Factory, Philadelphia.

pect a saving of about 25 per cent in the weight of a properly redesigned metal structure, compared with the corresponding original wooden structure, with a possible maximum saving of 50 per cent by refinement in design.

As an illustration, the wings of the original PN-10 type of flying boat were built of stick and wire to service-test the type of plane as soon as possible, since detailed design drawings and shop facilities for wood fabrication were immediately available. As soon as design personnel and metal-shop facilities were released, these wings were redesigned in duralumin, as shown in Fig. 1. Despite additional loading, which made the load factors for the metal wings about 10 per cent more than those for the wooden wings, a saving of 466 lb., or 24 per cent, was possible. Table 1 gives comparative weights of the wing sections, and of some of the more important details entering into its construction.

In hulls and floats the saving from metal construction is even greater. A weight comparison of a PN-7 wooden hull with a PN-10 hull, which is the same hull built of metal, shows a saving of 530 lb., or 23 per cent, from metal construction, the PN-7 wooden hull weighing 2340 lb. and the PN-10 metal hull weighing 1810 lb.

TABLE 1—RELATIVE WEIGHT OF PN-10 WINGS IN WOOD AND METAL

	Wood (lb.)	Metal (lb.)	Percentage of Saving
Upper Panels (two)	605	450	25.6
Engine Section	316	230	27.0
Sidewalks (two)	213	220	3.3 (loss)
Lower Panels (two)	631	470	25.5
Ailerons (two)	166	95	43.0
Total	1931	1465	24.0
Ribs (each)	1.53	1.17	23.5
Beams (each)	64.00	56.00	12.6
Ailerons (Uncovered, each)	73.00	37.50	48.6

In addition, there is the elimination of the soakage to which a wooden hull or float is subject in service operation, amounting to approximately 450 lb. in a hull of the PN type. Allowing for this, the metal hull makes a total saving of 35 per cent.

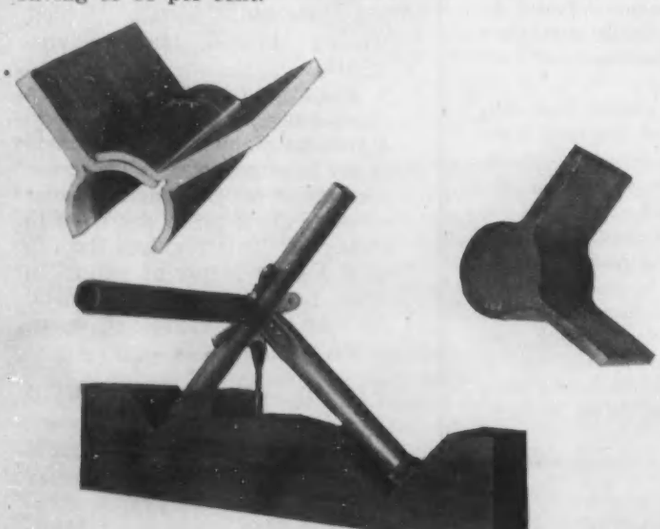

FIG. 2—FUSELAGE FITTINGS OF EXTRUDED DURALUMIN

The Main View Shows a Completed Fitting Set Up for Test. The Insert at the Right Shows a Short Section of the Extruded Metal from Which the Fitting Was Made. The Insert at the Left Shows a Method of Making a Similar Split Fitting from Metal Plate

Metal construction for a pair of PN-10 wing-tip floats resulted in a saving of 29 lb., or 20 per cent, as two PN-10 wooden wing-tip floats weigh 145 lb., and two PN-10 metal wing-tip floats weigh 116 lb.

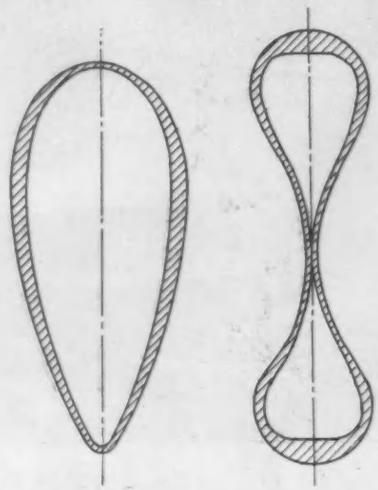

FIG. 3—EXTRUDED SECTIONS

The Streamlined Strut Shown at the Left Has Its Walls Thicker at the Sides Than at the Ends of the Section. The Section at the Right Is a Beam Having Walls Thickest at the Point of Maximum Stress

In the case of the twin-float seaplane TN-1, the best design that could be made in wood was estimated to weigh 600 lb. per float, while the actual metal float designed and constructed weighed 453 lb., making a saving of approximately 25 per cent.

The Navy has elected to develop the advantages of light aluminum-alloys and has concentrated its greatest effort on their improvement and application to the production of aircraft.

While steel is still the prevailing metal for fittings, an interesting production variation has been introduced in the case of the Navy TN-1 plane. The fuselage fittings have been designed so that they all can be machined from extruded duralumin of the single cross-section shown at the right in Fig. 2. This section is produced in lengths, from which are cut pieces corresponding to the over-all length of the particular fitting, the pieces being machined to suit. A fitting so made is shown in Fig. 2, set up for test after machining. The shop-production and design possibilities of this type of construction are very good. The fitting is an integral unit, without the possibility of poor welding, riveting or brazing to lower its design strength. If the extruded section is not available, a similar fitting can be built up in halves by splitting the ends of two pieces of sheet metal and bending them around the tubular longeron, as shown at the left in Fig. 2. The split type is especially adapted to quick repair, as such a fitting can be replaced by the removal of a few bolts.

Pressed construction reduces the number of parts, with a consequent saving in assembling costs. The Navy Department has kept in view the advisability of having designs for Naval aircraft adapted to the general shop processes of large automobile builders, so that, in time of National emergency, it can call upon them to produce designs on which they are equipped to start work immediately.

AN EXPEDIENT FOR SAVING DIE-COST

In a number of instances, it has been found lighter to press stiffening ridges into large flat sheets rather than

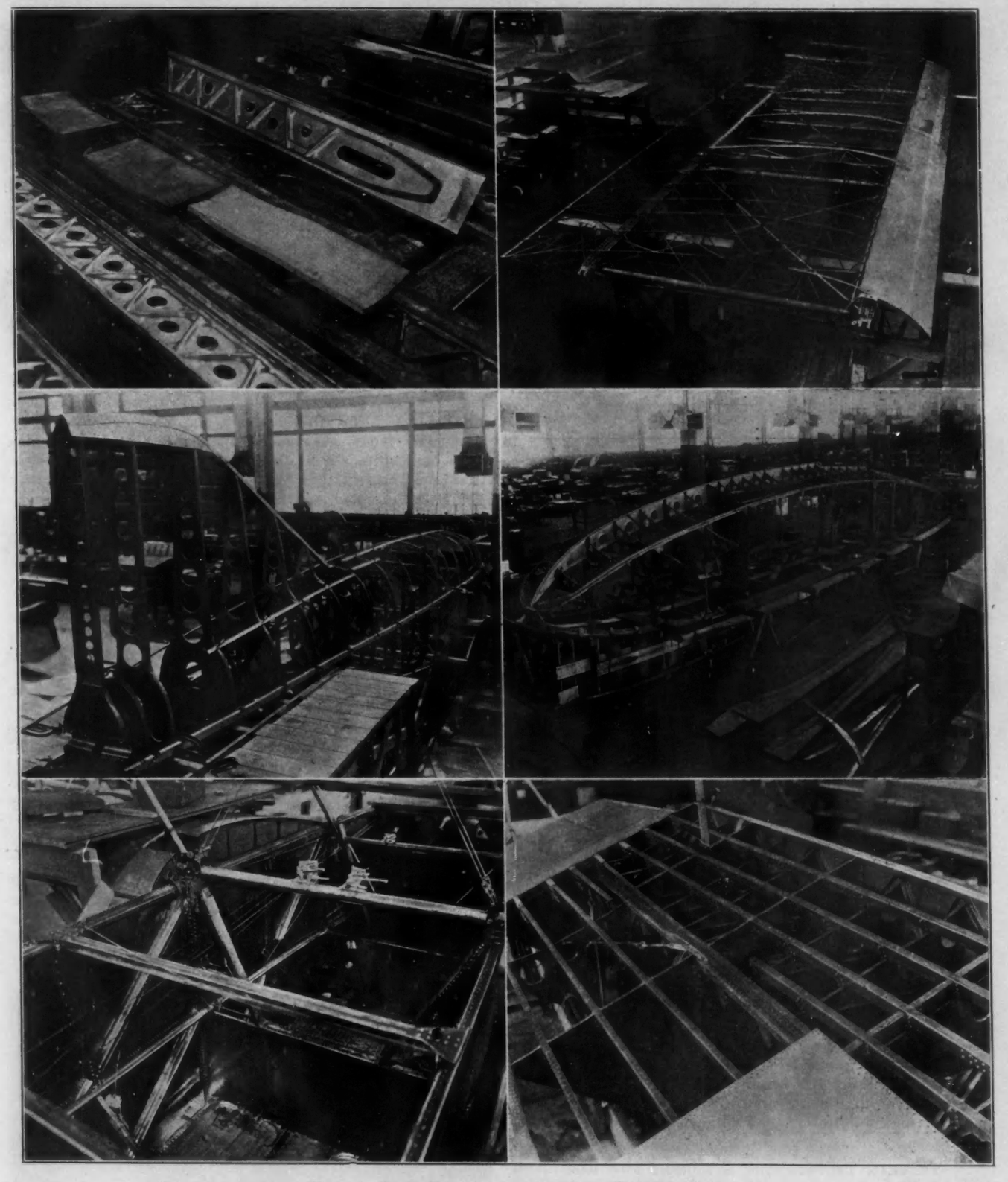

FIG. 4—SOME DETAILS OF AIRCRAFT CONSTRUCTION

For the Sheet-Metal Ribs of Experimental Planes and for Small Production a Single Die Is Made. With This Is Used a Sheet of Rubber, as Shown, Instead of a Matched Die

In Fuselage Frame of NM-1 Airplane the Bulkheads Were Reinforced with Structural Shapes. A Corrugated Skin Was the Main Strength-Member

Mid-Section of a PN-10 Flying Boat Showing Hull Frames Nos. 6, 7 and 8, also a Sidewalk and Engine-Support Braces. The Surface Controls Are in Place

This View of the Wing Construction of PN-10 Flying Boat, Shows the Form of the Tubular Ribs and the Pressed-Metal Beam. This Is the Engine Section, That Part of the Upper Wing Located Directly Over the Engines

The Keelson of PN-10 Flying Boat Was of Plate-and-Angle Construction with Standard-Die Flanged Lightening-Holes

View of the Bottom of the Hull of a PN-10 Flying Boat Showing the Z-Bar Longerons and the Central Portion of the Keelson, Where There Are No Lightening Holes

to add stiffening members. This was done to excellent advantage in the main bulkheads of the TN-1 metal floats. The method can be described briefly as the use in a press of a single die with sheet rubber, as shown in the upper left view of Fig. 4, in lieu of a second matched die. This single die may be of wood, metal or other material, depending upon the nature and amount of use anticipated. It may be cast, built up or machined from stock, depending upon which process is most reasonable for the work in hand and needs only to be finished to the tolerances and smoothness required in the completed article, because no fitting of male and female dies is required.

A variation of the process is to cast a lead female die directly from the male die as a mold, the lead die requiring no finish except hand scraping at the points where binding otherwise might occur. This is used as a follow-up to obtain a slightly sharper impression, after the first impression is made in the material with the sheet rubber.

While this process so far has been confined to experimental work and to cases where a small number of units

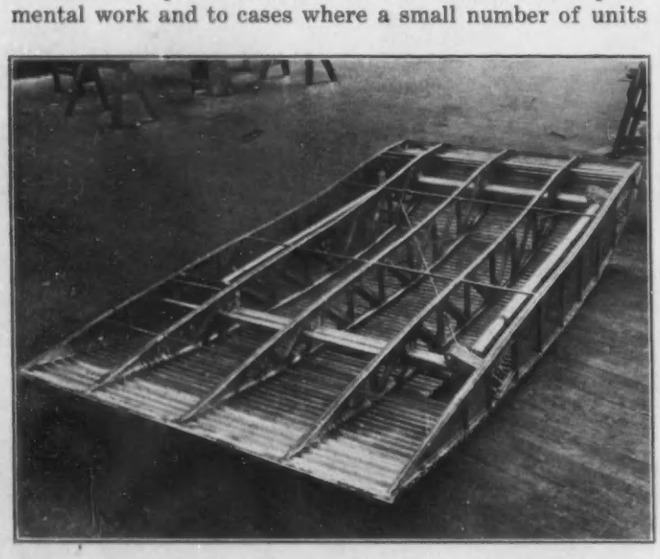

FIG. 5—SIDEWALK OF PN-9 PLANE
This Is a Bottom View Showing the Form of the Pressed-Steel Ribs, also the Corrugated Reinforcement for the Upper Surface

are to be made economically, it is reasonable to expect that, as its technique is further developed, it will have a much wider application. It develops a structure that is directly applicable to future production from conventional dies without making the costs prohibitive for an experimental airplane.

In addition to the extruded-metal fittings for the TN-1 plane previously mentioned, extruded work has been investigated for its possible use in streamline struts with a cross-section thicker in the side walls than at the short radii, and for elliptical beams thicker at the short radii, where there is a possibility of inserting tubes at the point of maximum stress. Two such sections are shown in Fig. 2.

TUBULAR TRUSSES ARE EFFICIENT FOR RIBS

Metal pressings were used in the ribs of the PN-9 plane in Fig. 5. While these were satisfactory, it is extremely difficult to compete with tubular members on a basis of strength-to-weight ratio in the case of extremely light and fragile members such as ribs, because of the necessity for maintaining a thickness of metal sufficient to resist corrosion. Therefore, when the PN-10 wings were designed, it was decided to develop in tubular con-

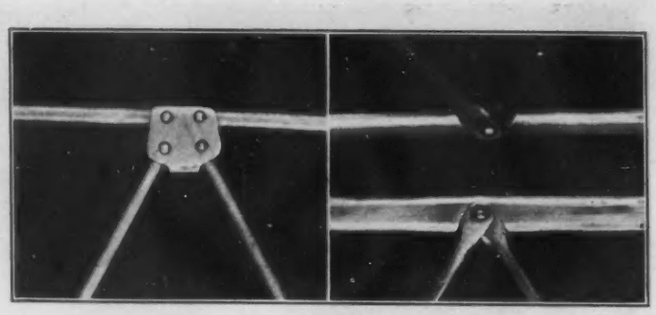

FIG. 6—JOINTS FOR TUBULAR RIBS
The View at the Left Is of the One-Piece Gusset Requiring Four Rivets, Used in the PN-10 Wing Shown in Fig. 6. The Single-Rivet Joint at the Right Is Now in Process of Development

struction the best strength-to-weight ratio possible with ease of fabrication. A section of the resulting wing is illustrated in upper right view of Fig. 4.

These tubular ribs, in conjunction with a pressed-metal beam, gave the very satisfactory weights listed in Table 1. For rib-gussets, a one-piece design employing four rivets was decided upon as giving best results. The next step will be to develop a split-end single-rivet joint without gussets. Experiments are now under way to determine the length of reinforcing tubes necessary to develop proper strength at such joints. The gusset at the left in Fig. 6 is the one used in the PN-10 ribs; the single-rivet joint is shown at the right.

FUSELAGE CONSTRUCTION

Airplane NM-1, illustrated in Fig. 7, was the first all-metal plane developed and built by the Navy. The fuselage employed bulkheads, reinforced with structural shapes as shown in the left central view of Fig. 4. These were covered with a corrugated skin that functioned as the main strength-member.

A parallel development of fuselage structure using extruded structural shapes tied together with gussets, very similar in type to the regular fabricated-steel building-construction, is also of extreme interest. This plate-and-angle construction is open and has very good production possibilities.

STRUCTURAL SHAPES ADAPTABLE FOR HULLS AND FLOATS

In the PN-10 hull, illustrated in the right central and lower right views of Fig. 4, the emphasis was placed on flat-plate frame-construction with reinforcing angles and channels. Standard-die lightening-holes were used wherever possible, but the main strength-members were

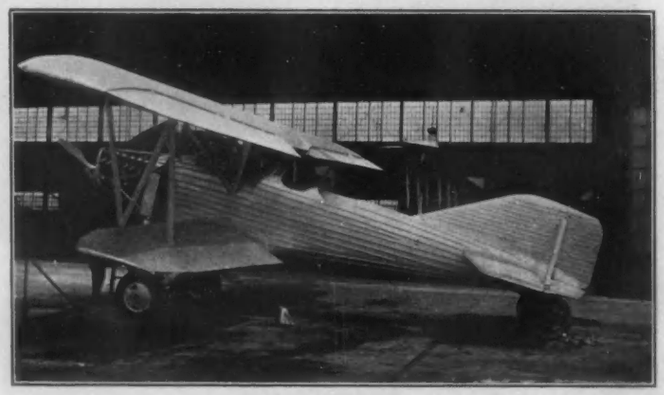

FIG. 7—NM-1 AIRPLANE
This Was the First All-Metal Plane Developed and Built by the Navy. The Fuselage Construction Is Shown in Fig. 9

not lightened. Main frames at beams, sections at water-tight doors and the doors themselves were metal pressings. The longitudinals were chiefly of conventional C-section channels with longerons of Z-bar construction, as shown in the lower right view. The keelson, seen directly above, was of plate-and-angle construction of the truss type, with lightening holes at points of minimum stress. Using the standard flanged lightening-hole throughout kept costs to the minimum and added considerably to the stiffness of the members. Flat-plate gussets and angle ties were used at all joints. This hull was of the F-5-L type.

The PN-11, now under construction, is of the NC shape with the continuous longitudinal system of body construction. A novel feature specified for this hull is that the gas tanks are built in, necessitating a variation from past structural practice. The hull will be made gas tight by the use of soft-aluminum liners between the plates. This feature calls for extremely careful workmanship throughout the hull, with exceptionally accurate fits. The hull is divided into five water-tight compartments with water-tight access-doors. In the planes of the front and rear beams there are additional frames to give strength and to act as fuel-tight bulkheads. These will not have water-tight doors but will be stiffened to take landing loads. Belt frames are used approximately every 4 ft., between water-tight frames. The principal fore-and-aft members are the keelson, sister keelson, chine and upper longeron, with bulb-angle longitudinals spaced about 8 in. apart between these members. Stiffeners are placed between the belt-frames, crossing beneath the longitudinals, attached by angle clips.

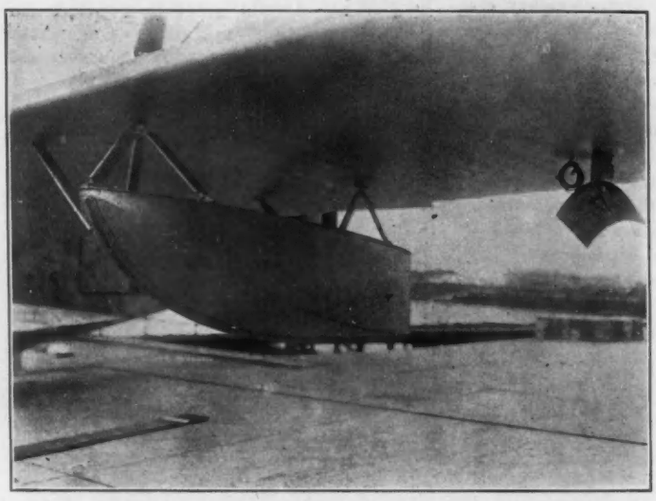

FIG. 8—METAL WING-TIP FLOAT OF THE PN-10 PLANE
The Float Is Attached to the Wing by Means of Struts Without Wiring

REFINEMENTS AND PRECAUTIONS

This hull has a concave bow, which gives better spray-action and reduces the number of stiffeners needed. Future models will be planned to carry this curve even farther aft. While rather difficult of fabrication otherwise, this design lends itself admirably to metal construction.

Metal is ideal for float construction. It makes a strong job that will resist puncturing from submerged logs much more successfully than wood, and it is possible to eliminate the usual wiring in wing-tip float attachments, as shown in Fig. 8. Stiffeners on the side skin can be arranged to form a truss, resulting in a material reduction in the frame-strength requirements.

It is feasible to make a metal seaplane practically crashproof, so far as the pilot's safety is concerned, by using monocoque cylindrical construction rather than tubular abaft the engine bulkhead, extending several feet back of the pilot.

Metal construction is a great improvement, being both economical in production and a great saver of weight. Its success, however, is dependent upon eliminating corrosion. This means that the engineer must design so that all parts are readily accessible. If closed sections cannot be avoided, they must be thoroughly cleaned, covered internally with protective coating, and adequately sealed. Contact between dissimilar metals must be eliminated by completely insulating them from each other, if it cannot be avoided otherwise. All faying surfaces must be covered liberally with water-tight protective-coating and bolted up before the coating has dried. All crevices and pockets should be sealed.

These principles having been introduced and executed by the designer and the manufacturer, the operating personnel must be indoctrinated and taught that they can maintain the structure in a safe condition only by frequent inspection and maintenance of the protective coatings.

Industrial Anomalies

EVERYBODY knows that the depression which in recent years has afflicted most of American agriculture, is broadly the result of over-production. However illogical it may seem that a too great responsiveness of the earth in bringing forth its riches is liable to mean poverty instead of wealth, it is a fact. In a logically organized society, doubtless it would not be true. The greater the production of wealth, the greater the well-being ought to be; only, it does not fall out that way.

The price of wheat has been depressed because too much wheat was grown. Last year the price of cotton went smash, because there were 4,000,000 bales too much cotton. Now another industry, quite unrelated to agriculture, but operating under the same inexorable laws of supply and demand, confronts the same situation. Less than a year ago people were wondering whence would come the petroleum needed to keep pace with a persistently increasing demand for it. Then set in a period of increasing production. New and rich oil fields were discovered; new production was brought in from lower strata of older fields; and better methods of refining, including particularly a wider use of the cracking process, suddenly completely changed the situation. Today, instead of a possible shortage, the industry's very riches in production, its constantly better processes, have brought to market such a huge output that the demand is outrun, and prices have for some time been on the down grade. So the industry finds itself traveling a road precisely parallel to that on which agriculture has been going.

Of course, such conditions inevitably remedy themselves in time. Both these industries are fundamentally sound and certain of an expanding market which will absorb that output and assure reasonable profits. This Country will never be impoverished by reason of a temporary excess of its riches.—American Petroleum Institute.

Selection of Materials for Aircraft Structures

By J. A. Roché[1]

Aeronautic Meeting Paper

Formulas giving rational criteria for the design of airplane members and for the selection of the most suitable materials are given by the author. These take due account of the physical properties of aircraft materials and of the resistance that result from the proper use of each.

Tables of relative strength-values are given. They show which materials are best for various parts and how much weight it is wise to add for a given reduction in parasite resistance or for a given increase in the output of the power-plant.

The properties of various materials are studied separately with relation to their functions, and indices are given classifying them in the order of their merit for tension and compression, and for beams and columns.

Conclusions are drawn showing which materials will be found most suitable for various vital parts of airplanes of different types.

OWING to the present strong tendency toward using metals and other materials to replace the vegetal materials such as wood and fabric, it is of fundamental interest to review the suitability of the standard structural materials in a rational manner, and thereby to guide the engineer in selecting the proper material for each structural part of the airplane. It is the purpose of this paper to set forth methods and values that will assist in answering, from the ideal technical point of view, the question of what material to use; for often an increment of weight will result in improvement of performance, and it is very important to know how much weight can be added in such cases before trying to decide what material finally should be selected. For aircraft use, materials must be compared on a basis that takes into account all the properties listed in Table 1.

TABLE 1—PROPERTIES OF MATERIALS

Material	Specific Gravity	Modulus of Elasticity in Tension, Lb. per Sq. In.	Ultimate Strength, Lb. per Sq. In.	Elastic Limit, Lb. per Sq. In.	Fatigue Limit, Lb. per Sq. In.
Spruce	0.43	1,300,000	9,400	.....	.....
Aluminum alloy	2.8	10,400,000	55,000	30,000	13,000
Chromium-molybdenum steel	7.85	28,000,000	95,000	60,000	40,000
Heat-treated chromium-molybdenum steel	7.85	28,000,000	175,000	145,000	85,000

The properties of high-strength wire and of tie-rods used in airplanes are fairly close to those of heat-treated chromium-molybdenum steel, the strength of the wire and tie-rods being obtained by mechanical working. Using the values of Table 1, comparison of materials for taking tension loads can be made immediately. Table 2 gives the specific strength for tension of the materials listed in Table 1, specific strength being the quotient of strength of materials divided by specific gravity. Table 2 shows that:

(1) Spruce is practically as good in tension as high-tension steel, although spruce does not lend itself easily to the making of efficient tension-connections

(2) Heat-treated chromium-molybdenum steel is superior to other materials for parts designed with the elastic limit as the criterion

(3) Both steels listed are better than aluminum alloy for parts subjected to alternating loads or to vibration. Practical experience is in agreement with this indication and most military airplanes in this Country have steel engine-mountings, even though the remainder of the structure may be composed of other materials

TABLE 2—SPECIFIC TENSILE STRENGTHS

Material	Specific Tensile Strength	Specific Elastic Limit	Specific Fatigue Limit
Spruce	21,900	.....	....
Aluminum alloy	19,600	10,700	4,650
Chromium-molybdenum steel	12,000	7,650	5,100
Heat-treated chromium-molybdenum steel	22,300	18,470	10,850

Table 3 shows the relative merits, of the materials listed, for resisting bending moments when only the most efficient proportions are chosen and the sections used with all materials are geometrically similar. Depth and deflections are of interest, because it is usually desirable to make airplane parts as compact and rigid as possible. The indices given are the ratios of the values of the following expressions for the various ma-

TABLE 3—INDICES OF MATERIALS WHEN USED FOR BEAMS

Material	Relative Weights of Beams of Given Strength	Relative Depths	Relative Deflections
Spruce	1	1	1
Aluminum alloy	2.18	0.56	1.27
Chromium-molybdenum steel	4.05	0.466	0.98
Heat-treated chromium-molybdenum steel	2.74	0.378	2.27

[1] Senior aeronautical engineer, materiel division, Air Corps, Wright Field, Dayton, Ohio.

terials to the value obtained for spruce. The derivation of these expressions follows, assuming that the sections for all materials are geometrically similar and have the same maximum bending resistance. The symbols used are:

W = Weight
G = Specific gravity of the material
M = Resisting moment
d = Depth of section, which is proportional to all other section dimensions
y = Deflection
f = Modulus of rupture, lb. per sq. in.
K = Coefficient, depending upon the section shape chosen; that is, a form factor
C = Coefficient, depending upon the length of the beam

Then

$$W = GCd^3 \quad (1)$$

$$M = fKd^3 \quad (2)$$

and from equation (2)

$$d = \left(\frac{M}{fK}\right)^{1/3} \quad (3)$$

Substituting equation (3) in equation (1)

$$W = GC\left(\frac{M}{fK}\right)^{2/3} \quad (4)$$

Since G and f are the only variables

$$W \propto \frac{G}{f^{2/3}}$$

$$d \propto \frac{1}{f^{1/3}}$$

and

$$y \propto \frac{1}{Ed^4}$$

The weight indices of Table 3 show that spruce would be by far the lightest material obtainable for beams if it could be used in sections similar to the best available with metals. Unfortunately, the low strength of spruce in directions other than along the grain makes this impossible, so that it has not actually the advantage shown by its weight index. Recent tests at the Materiel Division of the Air Corps show that metals, if carefully handled, can compete with spruce for spars.

The depth indices of Table 3 show the superiority of high-strength steel for use in parts exposed to air flow.

The deflection indices of Table 3 show that the high-strength steel will have larger deflections than the other materials and that spruce will give smaller deflections than the metals. Aluminum alloy seems to be the best material for beams not subjected to fatigue or exposed to air flow.

For compression members, it is very difficult to compare spruce with the metals, because similar sections cannot be assumed. The metals can be drawn into shapes having thin walls, and spruce cannot. Were it not for this fact, spruce, being the least dense material, could be used with lower values of slenderness ratio than metals and would excel for all parts not exposed to air flow. Practical experience shows that there is little difference in weight and drag between carefully designed solid spruce struts and hollow metal sections. The metals, however, have been very definitely compared for efficiency as long and short columns[2]. The conclusions of this comparison are as follows:

(1) For long columns all steels are equally efficient, since their moduli of elasticity are practically equal, but aluminum-alloy columns can be made having four-sevenths of the weight of steel columns

(2) For short columns the materials approach relative weights inversely proportional to their elastic limits and directly proportional to their densities as shown by Table 4. It is noteworthy that for blocks all the materials are almost equally efficient

TABLE 4—RELATIVE WEIGHTS OF SHORT BLOCKS OF DIFFERENT MATERIALS

Material	Relative Weights
Spruce	1
Aluminum alloy	0.875
95,000-lb. chromium-molybdenum steel	1.156
175,000-lb. chromium-molybdenum steel	0.756

Airplane parts can be differentiated according to the effect of air flow on design of sections and selection of material, as follows:

(1) Parts enclosed within covering and not limited in section dimensions. For these parts the indications given in the preceding study apply exactly

(2) Parts enclosed within covering and limited in section dimensions. For such parts each case must be tested by computing the weight of the part and assuming the most efficient section for each material, with constant depth

(3) Parts exposed to air flow. It is necessary to design such parts in several materials and with several sections for each material, then to compare their differences in weight and head resistance, with reference to the performance of the aircraft. It must be remembered that additional weight increases induced drag, even if the parasite drag is unchanged

For airplanes, air resistance has its effect on material and section selection in a very definite manner. The resistance coefficients of a great number of sections are available from wind-tunnel tests. It can be shown from the equations of steady flight that weight and parasite resistance have definite effects upon all the features of performance. Moreover, the effects of weight and resistance can be expressed in terms of each other, and such expressions can be used to determine just how far one should go in saving weight at the expense of drag, or vice versa. The expressions referred to are obtained by differentiation of the fundamental formula of head resistance[3]. The following symbols are used:

W = Weight of airplane, in pounds
A_e = Equivalent flat plate, in square feet
v = Speed of airplane, in miles per hour
S = Equivalent monoplane span of airplane, in feet
ρ = Density of air at altitude under consideration
R_c = Rate of climb of airplane, in ft. per min.
hp_a = Power available of airplane, or power delivered by propeller

At maximum speed, the relative effect of weight and drag is expressed by the formula

$$dW = -\frac{0.0000131\, v^4 S^2 \rho^2}{W} dA_e \quad (5)$$

If it is desired to obtain the best possible rate of climb, the relative effect is

$$dW = -\frac{0.288\, v^3 \rho}{R_c + \dfrac{22{,}000\, W}{vS^2\rho}} dA_e \quad (6)$$

Another pair of particularly interesting expressions states the relative importance of weight and power available as:

[2] See Air Corps Information Circular No. 568.
[3] See Air Service Information Circular No. 560.

For maximum speed

$$dW = \frac{3\,vS^2\rho}{2\,W}dhp_a \qquad (7)$$

and for maximum rate of climb

$$dW = \frac{33{,}000}{R_c + \frac{22{,}000\,W}{vS^2\rho}}dhp_a \qquad (8)$$

Equations (5) and (6) can be used to check the effect of changes that cause variation in the weight and drag of the airplane, for parts that are exposed to air flow. Equations (7) and (8) can be used to check the results of changes that affect the weight of the powerplant and the power available. These formulas can be used also to study any other materials that may be presented, such as magnesium alloys, rubber compounds and bakelite impregnated materials, as soon as their physical properties are completely known.

Values of these expressions for three typical airplanes are given in Table 5. The large figures corresponding to high speed must be taken only as rates that apply for relatively small increments of weight and resistance. For instance, a drag increment of 0.01 sq. ft. of flat plate will have very nearly the same effect on the high speed of the pursuit plane as the addition of 44.6 lb. of weight, but a drag increment of 1 sq. ft. will not have the same effect as the addition of 4460 lb. of weight. Thus it is plain that, for a pursuit plane, it is more important to seek dense materials such as steel for the struts rather than aluminum alloy, although struts of the latter material might be lighter, and even for hollow steel struts it is advisable to use a ratio of gage to outside dimensions far greater than that resulting in the greatest weight economy from the structural viewpoint.

TABLE 5—VALUES OF DERIVATIVES OF AERODYNAMIC FORMULAS

	Light Plane, 600 Lb.		Pursuit, 3000 Lb.		Transport	
	High Speed	Climb	High Speed	Climb	High Speed	Climb
$\frac{dW}{dA_e}$	845	38.7	4,460	96.2	1,850	93
$\frac{dW}{dhp_a}$	230	47.9	104	12.85	108.5	25.2

To obtain the best rate of climb it is less important to eliminate parasite resistance than in the case where maximum speed alone is wanted, so that for all except pursuit and racing airplanes the rate-of-climb figures should be used to compare parts having different weights and air resistances.

The value of weight derivative with respect to power shows that a 1-hp. increment in the power available at the propeller of a transport airplane is worth an addition of weight of at least 25.2 lb. Thus, if this increment of power can be obtained by substituting a steel propeller having very thin sections and weighing not over 25 lb. more than the propeller originally contemplated, the substitution should by all means be effected; for it will result either in a better speed and rate of climb, when full engine power is used, or in a fuel saving, if the additional power available is not used. In either case the range of the airplane will be improved.

Up to this point the physical properties of materials and the aerodynamic properties of parts made of various materials have been discussed, but there are other factors which enter into the problem of material selection, namely:

(1) Cost
(2) Possibility of welding and bending
(3) Necessity for heat-treating
(4) Resistance to corrosion
(5) Desirability of using as few different materials as possible
(6) Ease of design; for example, weldable materials facilitate design of joints

In conclusion, it may be said that weight and strength are so important to an airplane that no single material yet discovered combines the necessary physical properties to recommend its use for all parts. Each part must be studied with respect to its position and function.

From perusal of the tabulated values, it is logical to expect that:

(1) Exposed struts will be streamlined steel tubes for pursuit and racing airplanes and streamlined aluminum-alloy tubes for transports
(2) External bracing will be accomplished with as few struts as possible, such trusses being chosen as consist mostly of streamlined tension-rods
(3) Engine mounts for all types of plane will be mostly of steel, and the portion of the fuselage aft of the engine mount will be an aluminum-alloy truss or shell
(4) Spars of small externally braced thin wings will be of spruce and simple duralumin sections, while spars of large internally braced thick wings will be metal trusses
(5) Wing ribs will be of spruce or aluminum alloy in all types of airplane
(6) Propellers of large transports will be of aluminum alloy; while those of fast airplanes will be of high-strength steel, because of its greater specific fatigue resistance and the higher efficiency possible with very thin sections

Widening Roads

WITH the number of cars on the road; with the necessity of a car for certain businessmen, salesmen, and others; with the women rivaling the men in the number of drivers; and the dependence of commerce on motor transportation, the question of motor law is a very insistent one, and the motor condition today is such that it is at any moment apt to descend with all its force on some particular individual. By a sure knowledge of speed rates, the rules of the road, the right-hand rule, that is, the rule as to the right of way to be given to a vehicle approaching from the right, and the other rules, many, and tiresome, perhaps, to learn, but very important for all that, the driver can in many instances, by recognizing the right thing to do, avoid trouble, spare himself annoyance and add his little bit to the peace of this world by paying constant attention to that so very often forgotten but nevertheless always advisable requirement of exercising carefulness when driving.—F. A. Fullhardt in *New York Motor News*.

Standardization Tests in the Wind-Tunnel

By E. N. Fales[1]

Aeronautic Meeting Paper *Illustrated with* Charts and Photographs

The wind-tunnel has been an indispensable aid to aeronautical progress, but two defects in the technique of wind-tunnel testing have not yet been overcome. First, the aeronautical engineering coefficients derived from wind-tunnel tests of small-scale models often require correction for scale effect before they can be applied to a full-size design. The use of this scale-correction factor has not been standardized. Secondly, the results obtained from different wind-tunnels do not always check, and uncertainty regarding the correctness of the coefficients may result.

Studies with regard to the reasons and remedies for these two defects have been made for several years at the McCook Field wind-tunnel. The data are discussed and it is shown that the models and methods may be used profitably for standardization work in other tunnels.

ALTHOUGH it is a specialized factor in the progress of aeronautics, the wind-tunnel has been indispensable. It is not known generally that it was by means of a wind-tunnel that the Wright brothers first established the science of aviation, tested many different wing shapes, and arrived at the coefficients upon which their success was based. Later, the Eiffel tunnel showed Nieuport how to improve the speed by streamlining and enclosing the fuselage; the English tunnels produced a working theory of flight stability; and the German tunnels evolved the thick wing. Today, designing offices everywhere use wind-tunnel tests for predicting the performance of proposed aircraft, and depend on them almost exclusively for making aeronautics an exact science, a far-distant goal for the attainment of which much research remains to be done that can be accomplished only by the aid of the wind-tunnel. The object of this paper is to consider some important details of wind-tunnel technique which affect its future usefulness. Some undesirable aspects that must be remedied are discussed, and McCook Field researches on standardization of wind-tunnels are described.

If a wind-tunnel were a cheap simple compact apparatus, like a microscope, it would be used in every airplane factory, technical school and Government bureau and even in private homes, because it is the source of nearly all of our knowledge of the dynamics of the air. But it is expensive. The size is so large that at the new Air Corps Experimental Station at Dayton, Ohio, for example, the new 10-ft. wind-tunnel building is one of the most conspicuous buildings on the field. In aeronautical development budgets, wind-tunnel items have too often been cut in favor of more direct needs. Few have been built, 100 in all, one-quarter of which are in the United States. The majority are forced, by economy, to be operated under conditions that are far from ideal.

A wind-tunnel laboratory is difficult to operate even under the best conditions. It deals with a capricious sensitive invisible substance; namely, air in motion. Operations are necessarily tedious and confining, requiring scrupulous care and constant surveillance to guard against obscure sources of error. Any compromise in the adequacy of equipment, space, power supply, personnel, and the like, can be, and too often has been, fatal to reliability and productive of misleading results.

When the French and English began to cooperate during the war, the English wind-tunnels could not always duplicate the French results. Since then, discrepancies between the different tunnels of the world have continued to appear, and have indicated that, aside from legitimate scale-effect corrections, unknown variables in the technique of wind-tunnel testing still exist that must be brought to light and overhauled. For example, universal adoption of thick wings was delayed for a year because all tunnels at first did not corroborate the favorable coefficients reported from Germany, where thick wings were first exploited during the war.

An aircraft designer cannot be blamed for becoming bewildered when, for example, wind-tunnel No. 1 predicts, from a model test, that his design will have a landing-speed of 75 m.p.h., and wind-tunnel No. 2, testing the identical model, predicts 70 m.p.h., whereas, later, a full-scale test shows 65 m.p.h. to be correct. Or, when attempting to "scale-up" published coefficients for some part of his work, he finds the "scale-correction" factor itself to be controversial and even arbitrary.

It is obviously disconcerting to all concerned, when, as has happened, a purchaser, contracting for the design and construction of a proposed aircraft, stipulates that the model, in preliminary wind-tunnel tests, shall show a resistance of a given minimum amount; and when, after the test of the model has been made, a resistance coefficient is obtained which, although accurately and truly measured, is unreasonable and unusable because of the insufficient size of the model and the excessive scale-effect.

Or, when, as in another recent case, the purchaser and the contractor each makes his own wind-tunnel test, in different tunnels but with the same model, and then disagree by several degrees as to the proper setting of the stabilizer.

The wind-tunnel specialist, quite familiar with the in-

[1] Aeronautical engineer, Dayton, Ohio.

tricacies of the technique and of the scale-effect, is not alarmed by these occasional discrepancies, which he regards as necessary growing pains, to be cured by future progress. But only a few instances of this sort are needed to bring wind-tunnel testing into exaggerated disrepute with designers and contractors, who have been heard to complain, both abroad and in this Country, that the wind-tunnel is not yet a perfected instrument. As a result, in some parts of Europe the merits of the wind-tunnel have not yet been granted widespread recognition.

This is not the case in the United States, however, thanks to authoritative support of wind-tunnel methods by the National Advisory Committee for Aeronautics, and, more lately, by the Daniel Guggenheim Fund for the Promotion of Aeronautics.

Wind-Tunnel Standardization a Vital Need

Remedy for the above complaints resides in a program of standardization; that is, in a series of tests of identical models in all existing tunnels, the tunnels cooperating to determine what are the discrepancies between one another's work and what are the reasons therefor.

Such a program has been in operation for several years in this Country and in England under direction of the National Advisory Committee for Aeronautics and the British Aeronautical Research Committee. The models concerned have been airships, airplanes, airfoils, cylinders, discs, and a model propeller. The National Advisory Committee also made some tests of spheres in its 5-ft. atmospheric tunnel. Spheres, cylinders, and airship models are very sensitive to wind-tunnel peculiarities; the results obtained in one tunnel may differ as much as 100 per cent from those of other tunnels.

Occasional interchanges of tests have been made between individual tunnels. For example, there are at McCook Field two dozen airfoils that have also been tested in the Massachusetts Institute of Technology tunnel. There is an airfoil that has been tested both at McCook Field and at Göttingen. Comparisons have been made between the McCook Field, the Curtiss and the National Advisory Committee tunnels. It is by such mutual comparisons that standardization data develop.

It is thought that attainment of the desired goal will be hastened in proportion as centralized supervision is furnished, by the National Advisory Committee for Aeronautics or by some other similar organization, for all standardizatin tests in the United States and, if possible, abroad. The value of the program will be increased if each test in the different tunnels be supervised personally by the same individual, who will, at the conclusion of the program, make a coordinated report on the whole.

The problem of standardization has been particularly obvious in the Army Air Corps, where matters of design, and even of contracts, have involved aerodynamic coefficients determined in two, and sometimes in four, tunnels geographically distant from each other. In 1924 some special researches were therefore begun, with the object of (*a*) subjecting the Army wind-tunnel to rigid self-examination, and (*b*) systematically analyzing the chief variables which affect the technique in all tunnels; namely wind speed, flow turbulence, and model size. Some of the models used had the peculiar merit of being very sensitive to these variables and of recording the effect on the *lift* curve. Heretofore, models of equal sensitivity, as spheres, streamlines, and cylinders, have had no lift curve. The lift curves are less susceptible to error than the drag curves. So much benefit was received from these tests for the improvement of our own technique, and so suitable for standardization tests were the models used, that both the method and the models are thought appropriate for similar standardization study in other tunnels.

Standardization Tests in McCook Field 5-ft. Tunnel

The McCook Field tests can be summarized only briefly here. The main tests occupied more than 6 months' continuous work and have been described in a 200-p. report, the Effect of Speed, Turbulence and Model Size on the Reliability of the McCook Field Wind-Tunnel, Airplane Department Memorandum No. 901. Supplementary tests were described in reports under the following headings filed at McCook Field:

The Effect on Model Coefficients of Reducing the Honeycomb Turbulence in the McCook Field 5-Ft. Wind-Tunnel, Airplane Department Memorandum No. 821

Calibration of McCook Field 5-Ft. Wind-Tunnel with Duplex Straightener at Intake and Honeycomb Removed, Serial No. 2636

Tests of 20 Propeller Airfoils on National Physical Laboratory-Type Balance, Airplane Department Memorandum No. 851

An Attempt to Extend Tests on 20 Propeller Airfoils by High-Speed Tests, Airplane Department Memorandum No. 887

Spindle and Spindle-Guard Effects on Lift and Drag, Airplane Department Memorandum Nos. 847 and 848

Visual Study of Flow Discontinuity on a 0.15-Camber Airfoil, Airplane Department Memorandum No. 748

Also a large number of tests on airplane models

Purpose of the Tests

The object was, first, to examine the reliability of the McCook Field wind-tunnel and, so far as the analogy applied, that of all wind-tunnels. The method of making the examination was to observe the change of force on given airfoils when tunnel flow-conditions were changed. Airfoils of peculiar shape, having unusual sensitiveness to these changes, were chosen for this purpose. A second object was to improve the reliability of the tunnel, and to develop new apparatus and technique of testing.

Some of the problems investigated were to determine:

(1) The largest size of model that could be tested successfully

(2) The effect of making tests at high velocities on large and small, thick and thin airfoils, the tunnel being capable of speeds as high as 300 m.p.h.

(3) The limiting speed above which the coefficients ceased to change or reversed their rate of change

(4) The effect of turbulence on the air-flow

(5) The reliability of conventional wind-tunnel test-methods when extended to cover high-force tests at widely varying speeds. Study of contributory details, such as flow-alignment, methods of supporting the model, precision of the apparatus, and the like

Improved Technique Resulting from the Tests

Results of the tests have been the basis of important changes in our tunnel, among which are the following:

(1) The small conventional 3 x 18-in. model has been discarded as standard and the 6 x 36-in. model has been adopted. This is unusual in a small 5-ft.-diameter tunnel, but the tests showed that the larger size gives more consistent results in spite of wall interference. The smaller sizes

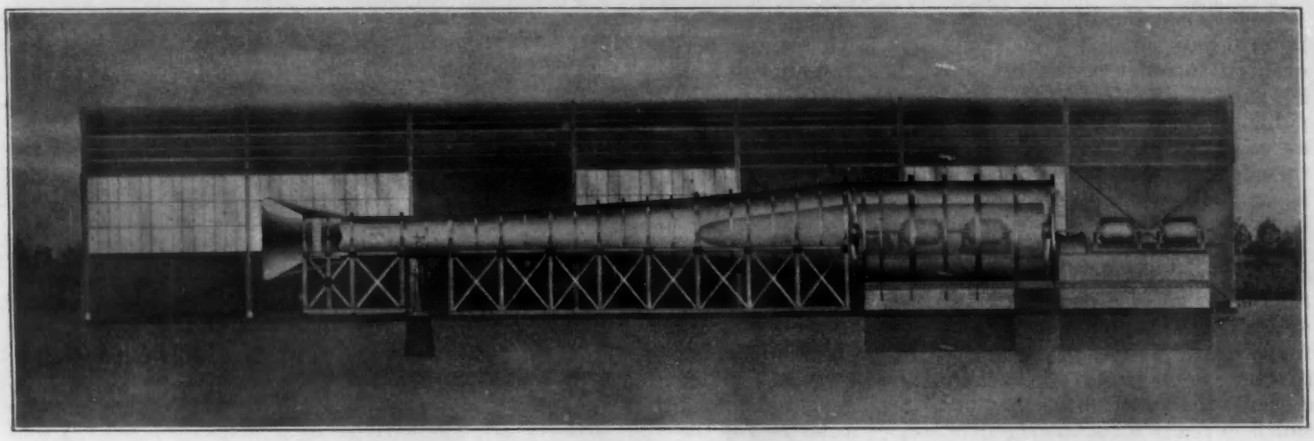

FIG. 1—MCCOOK FIELD 5-FT.-DIAMETER WIND-TUNNEL FOR TESTING AIRFOIL MODELS

are more liable to error than are the large sizes

(2) The Reynolds number alone was shown to be insufficient basis for comparing two wind-tunnel tests, turbulence was found to be of considerable importance in accounting for discrepancies between different tunnels, and a pressing need was found to exist for further studies of the overlapping of the two effects

(3) The turbulence in our wind-tunnel was reduced to a small fraction of its original value by a novel "straightening" apparatus to make the texture of flow as nearly as possible similar to that under full-flight conditions

(4) One of the most obvious discrepancies; namely, the unreliability of the burble-point or landing-speed characteristics of wind-tunnel models; has been settled. This has been established as due to differences in speed and turbulence in the different tunnels

(5) The 0.15-camber cylindrical-airfoil series was found to be a sensitive indicator of the three factors causing discrepancy. By means of these airfoils the unreliability mentioned in item (4) above can be studied, not only at the landing speed, but also at the flying speed and at the zero lift; for these peculiar airfoils exaggerate effects ordinarily too small to be noticed in conventional models

(6) It was demonstrated that no need exists of running tests at velocities higher than 150 m.p.h.; to prove this, velocities approximating our top limit of 300 m.p.h. were required. A speed of 40 m.p.h. is too low for general use

(7) A high-force wire-balance capable of accommodating the very wide speed-range available in our tunnel was developed

(8) Standard methods of high precision were adopted in all tests, as it was found that, when the speed is widely varied in a test, errors are more likely to arise than in the single-speed type of tunnel. This is especially true of thick airfoils. We now test all models in the erect and again in the inverted position

(9) The shift of the zero-lift angle with speed has been identified as a local effect in the lift curve demanding a special scale-correction at one location rather than a blanket correction for the whole curve. It has been shown that the v^2 law must be discarded in propeller calculations dealing with the zero-lift angle, since the lift for small airfoils in this region varies more nearly as v^3. In conjunction with Airplane Department Memorandums Nos. 887 and 851, tests on 20 Propeller Airfoils, it has been suggested, therefore, that propeller-airfoil coefficients, at least for the thicker sections, should be taken from models larger than 3 x 18 in.

THE MCCOOK FIELD WIND-TUNNEL

The distinguishing features of the apparatus and the method used were:

(1) Models were used that were peculiarly sensitive as detectors of turbulence, speed, and size effects

(2) The speed range was wide; namely, from 10 to 260 m.p.h.

(3) Precision of the most painstaking sort was the policy

(4) Three degrees of turbulence were used, giving the effect of having three different tunnels

Two series of models were used. The first series comprised eight cylindrically cambered models, as above, geometrically similar but varying in size from 1 x 6 to 8 x 48 in. Each model had a flat bottom and a cylindrically arched top-surface, with a maximum thickness about 0.15 of the chord and located at the mid-point of the chord. The leading and trailing edges were rounded off slightly for practical reasons. Great care was used in making the models; they were turned on the lathe and the metal ones, from 1 x 6 to 5 x 30 in., were ground. The wooden models were damp-proofed by covering them with aluminum leaf.

The second series of airfoils consisted of five thin racing airfoils; namely, the Curtiss C-27 wing; each made by the Nichols Co., geometrically similar and varying in size from 2 x 12 to 6 x 36 in. This series was tested as supplementary to the 0.15-camber-airfoil series, so that conclusions might be based on a conventional airfoil as well as on the 0.15-camber airfoil.

The models used were chosen for their sensitiveness to change of flow-conditions, without regard to their applicability to aircraft design. It is necessary to emphasize this point, because the most useful model of the series, a cylindrically cambered flat-bottomed section, gives a coefficient graph which, considered as an airfoil graph, is peculiar and confusing, showing the effects of speed, size, and turbulence to a more exaggerated extent than is usual.

It is a property of thick cylindrically cambered airfoils that the lift coefficient, at angles below 8 or 10 deg., is strongly affected by changes in Reynolds number

or turbulence, but at angles above 8 or 10 deg. the effect is relatively small. Thus, for high Reynolds numbers or high turbulence, the lift curve has a hump at 8 or 10 deg., rising later to the maximum lift, or burble-point, at about 18 to 20 deg. In other words, the lift curve has two humps. For low Reynolds numbers, or low turbulence, the 8-deg. hump becomes a depression; that is, as the angle is increased, there is a sudden violent increase in the lift coefficient[3].

The phenomenon is familiar in the drag curves of spheres and cylinders, but it exists in conventional airfoils to so small a degree that it has heretofore escaped notice and is unfamiliar. The graphs will therefore be found to have a shape unlike ordinary airfoil graphs; in fact, some name other than "airfoil" would better describe the function of the cylindrical cambered model, which is really a turbulence detector, or a device for the study of Reynolds number.

Speed Range from 4 to 300 M.P.H.

In the McCook Field wind-tunnel shown in Fig. 1, where propulsion is by two independently driven propellers, either or both can be put into operation, so that practical operating conditions can be secured as low as 4 m.p.h. or as high as 300 m.p.h. In the present tests, 10 m.p.h. was the minimum velocity used, and 260 m.p.h. the maximum, giving a 26-fold range.

This high range, incidentally, is one of the reasons that scrupulous regard to questions of test precision was necessary. It was requisite to know the degree of change of the velocity calibration with the air speed; also the change of flow-direction alignment. Velocity calibration was originally made at two speeds, one high and one low, intermediate calibration being taken by interpolation, the change from low to high being small in any case.

To care for change in flow alignment, it was not thought proper to count on this remaining the same for different speeds, for different airfoils, or even for different days, on the same airfoil. Tests were therefore run, in general, with the model first in the normal position, then in the inverted position. Meanwhile, of course, the balances, which were so constructed as to be easily adjusted for accommodating air-flow misalignment, were maintained in as neutral a position as was practicable.

The effect of rapidly growing forces on the balance, with the resulting deflections in the parts, was kept under constant surveillance. Two balances were used, one the British National Physical Laboratory-type balance for small forces of a few pounds, and the other the wire balance for forces up to 200 lb. Precise work over such ranges is impracticable for a single balance of the conventional type. Fig. 2 is a diagram of the wire-balance system, and Fig. 3 shows the operator at the telescope, with electrical controls for wire adjustment.

Effect of Speed on Lift

Study of the speed effect was facilitated, not only by the wide speed-range of the tunnel, but by the peculiar form of the model used. This, as explained elsewhere, was unusually sensitive to changes of size, turbulence and speed. A typical set of curves is shown in Fig. 4, for a thick, and in Fig. 5, for a thin, airfoil. Note that the lift curves in Fig. 4 between 8 and 22 deg. are not much affected by velocity, but that for angles lower than 8 deg. the effect is great. Consider, for example, the 30-m.p.h. curve. As the angle increases from minus 4

[3] See Airplane Department Memorandum No. 851, Tests of 20 Propeller Airfoils, Nos. 134 and 135; also Cowley and Levy Wings A-1 to A-7, tested at the British National Physical Laboratory.

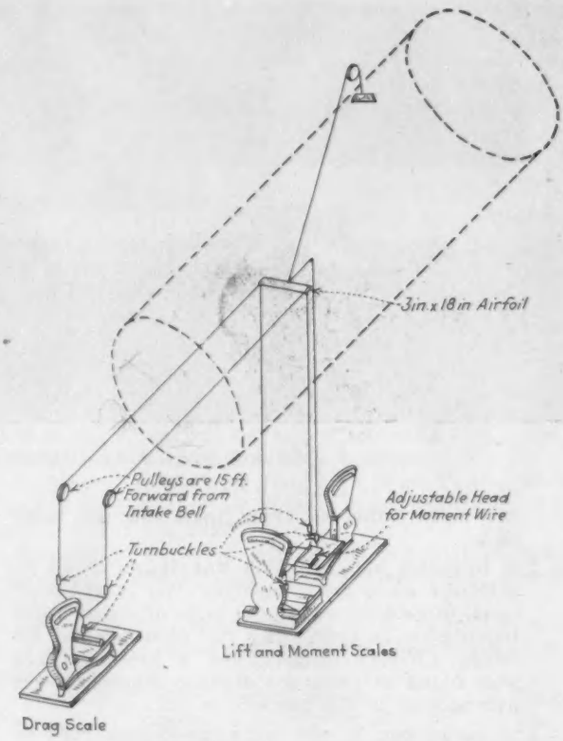
3in. x 18in. Airfoil
Pulleys are 15 ft. Forward from Intake Bell
Adjustable Head for Moment Wire
Turnbuckles
Lift and Moment Scales
Drag Scale

Fig. 2—Diagram of Wire Balance-System

This Was Constructed To Be Easily Adjustable for Accommodating Air-Flow Misalignment. It Was Built for Measuring Forces up to 200 Lb. That Are Too Great for the Spindle-Type Balance. Precise Work over Such Ranges Is Impracticable for a Single Balance

to plus 10, the curve is continuous. At 10 deg., however, flow discontinuity occurs and a new lift-curve comes into existence, corresponding to a flow regime of higher efficiency. The higher velocities, 40, 60 and 80 m.p.h., produce higher coefficients in the lower angle-range, the discontinuity occurring at an earlier angle until, at 100 m.p.h., discontinuity is not in very strong evidence.

We see, then, a sheaf of lift curves that lie fairly well together at large angles but spread apart violently at the lower angles. Naturally, these widely dispersed lift-curves are accompanied by a strong shift of the zero-lift angle and throw increased light on our knowledge of zero-lift phenomena.

This speed effect has its counterpart, much less striking and without flow discontinuity, in the case of the conventional thin airfoils, as shown in Fig. 5. The lift dispersion is a characteristic of the airfoils rather than of the tunnel flow. It entails a departure from the v^2 law and shows that at this part of the lift curve; that is, the low-drag region, the most important part for the airplane designer; a special scale-correction must be used that is not applicable to the higher lift-angles.

The effect of speed on lift is strikingly shown in Fig. 6, a special speed-run in which all factors were held constant while the speed was progressively increased. As lift is plotted against v^2, any departure of the curves from a straight line represents departure from the v^2 law. Note that for the lower angles there is considerable departure. The significance as regards zero-lift-angle phenomena is great; for example, a given model at a given angle of attack may be given a positive or a negative lift at will by increasing or decreasing the velocity. The 3 x 18-in. model has zero lift at an angle of minus 2.75 deg., when $v = 50$ m.p.h. Suppose the airfoil is held at this angle but the speed is increased; there will be a

positive lift at all speeds higher than 50 m.p.h. Suppose the speed is decreased; there will be a negative lift at all speeds lower than 50 m.p.h. Between 30 and 70 m.p.h. the drag coefficient remains approximately constant but the lift coefficient changes rapidly with the speed.

The effect of a change of speed from 30 to 70 m.p.h. is best described as an upward swinging of the resultant force-vector, as in the three cases in Fig. 7. It is seen that, roughly, the phenomenon is a progressive, continuous one that operates chiefly on the lift, rather than, as would ordinarily be expected, on the profile drag. A possible reason for this effect may be inferred from study of the boundary layer of an airfoil, as described later. The inference is that at low velocities the flow over the convex upper camber of the airfoil separates from it some distance ahead of the trailing edge, perhaps due to the normal formation of a boundary layer toward the rear of the airfoil. The air beneath the airfoil, meanwhile, after burbling around and under the leading edge, has regained contact with the flat under surface and clings to the rear part of it, leaving the trailing edge in a slightly upward direction. The net deflection of the upper and the lower air-flows is upward, and the lift is negative.

This inference would indicate that, at 70 m.p.h., the boundary layer is now mixed with the main upper flow because of the higher velocity, producing a sort of scouring action. The upper flow therefore clings more easily to the convex upper camber and does not separate until it is relatively close to the trailing edge, by which time it has "gone over the hill" and has acquired a downward deflection. Perhaps, also, the lower air-stream at the higher velocity cannot regain contact with the under flat surface. At any rate, the net air-deflection is downward and the lift becomes positive.

The function of the boundary layer has recently been shown[3] empirically at Göttingen to have a surprisingly great effect on the lift.

[3] See translation in National Advisory Committee for Aeronautics Technical Memorandum No. 395; also, for Tests on Boundary Layer Removal at McCook Field, see Airplane Department Memorandum No. 842 and THE JOURNAL, May, 1927, p. 575.

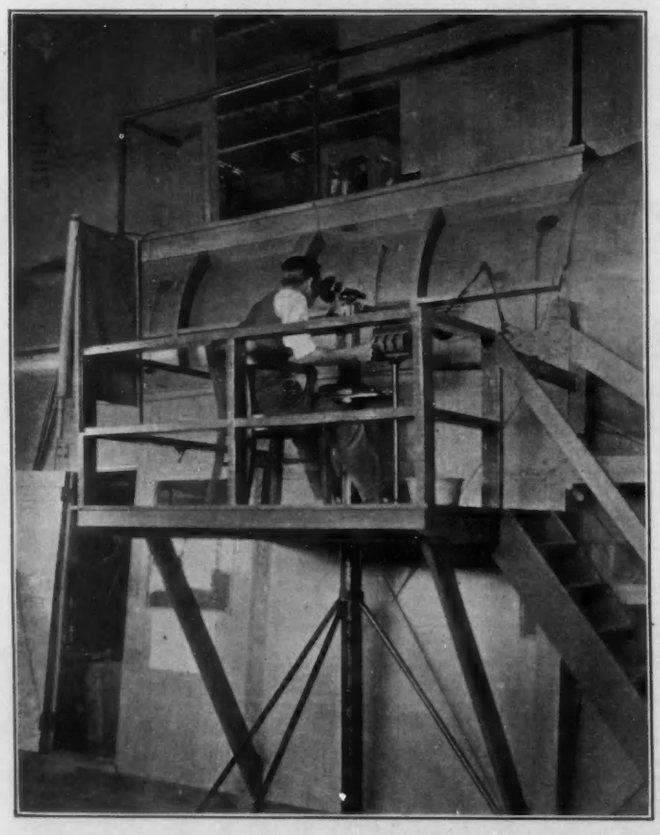

FIG. 3—METHOD OF OPERATING THE WIND-TUNNEL

The Operator Is Shown at the Telescope, with Electrically Operated Controls for Maintaining the Model in a Fixed Position

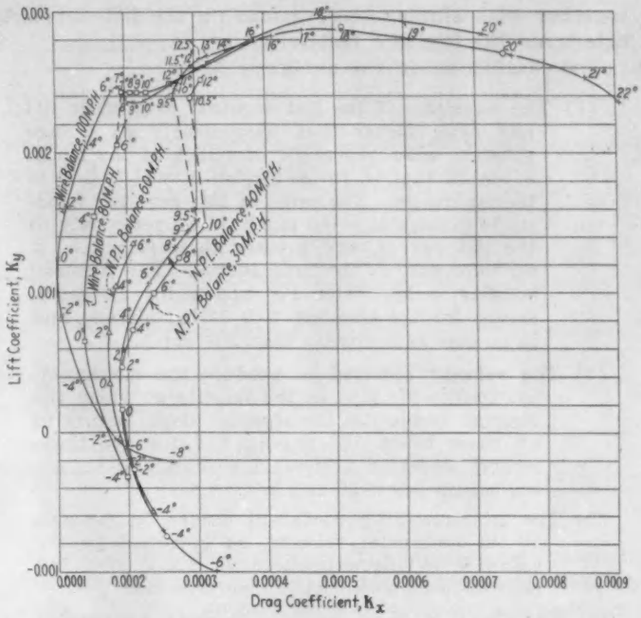

FIG. 4—EFFECT OF SPEED ON 3 X 18-IN. 0.15-CAMBER CYLINDRICAL AIRFOIL

The Curves Are the Means of Tests with the Airfoil in Erect and in Inverted Position and with the Duplex Straightener in Use. Wall-Interference Corrections Are Not Shown. For Angles between 8 and 22 Deg. the Lift Curves Are Not Much Affected by Velocity, but for Angles Less than 8 Deg. the Effect Is Great

LIMITING VELOCITIES FOR WIND-TUNNEL TESTS

From the speed curves it is possible to form an estimate as to the limiting velocity above which the lift and the drag coefficients do not change greatly. In general, both the drag coefficient, K_x, and the lift coefficient, K_y, change rapidly with v at low values of v, but the rate of change of K_x and K_y decreases to a comparatively low figure at high velocities.

The lift-v^2 charts show that K_y increases with v until the point of the curve is reached that is tangent to a vector passing through the origin. For this velocity, K_y will be greater than at any other part of the curve, and the rate of change in K_y is zero.

Again, there is a velocity on each lift-v^2 curve above which the curve is straight. This velocity and the maximum K_y velocity do not differ greatly. At both velocities the rate of change of K_y is small. At higher velocities the falling off in K_y is very small, being governed by the value of K in the expression, $L = K + Cv^2$. It is from examination of these velocities that our conclusions have been reached regarding the limiting test-velocities for the McCook Field wind-tunnel.

For the drag-v^2 curves, the typical case shows K_x to be the maximum at zero velocity and to decrease rapidly until the curve becomes a straight line, after which further decrease is small. The speed at which the curve becomes a straight line has been tabulated and is used,

together with similar observations on the lift curve, to determine the limiting test-velocities.

The conclusions in the summary are:

(1) The velocities of the test required to produce lift and drag forces that vary nearly as v^2 are greatest when the angle of attack of the model is small; that is, in the region in which L/D is the maximum. The value of this required velocity is greater than 60 m.p.h. if we refer only to the lift curves, and greater than 40 m.p.h. if we refer only to the drag curves. The required velocity is less than 170 m.p.h. for all cases, except for the smallest, 2 x 12-in., airfoil; and in no case is it greater than 200 m.p.h.

(2) The velocity required to produce the maximum-lift coefficient; that is, the velocity at which the tangent vector has the steepest slope; occurs in all cases below 150 m.p.h.; and for the three largest models, 6 x 36-in., 7 x 42-in. and 8 x 48-in., occurs below 90 m.p.h.

(3) The minimum-drag coefficient occurs, in general, at the maximum velocity, as governed by the value K in the expression $D = K \times Cv^2$, but falls off very slowly at higher velocities

(4) For the 6 x 36-in. model, the drag approaches very close to its asymptotic values at velocities lower than 140 m.p.h. Therefore, the conclusion is that on 6 x 36-in. thick airfoils in the McCook Field 5-ft. wind-tunnel no advantage is gained by running the tests at speeds higher than 140 m.p.h.; and 120 m.p.h. is usually high enough

(5) For the 3 x 18-in. model, the same conclusion is reached; namely, no advantage is obtained by running the tests at speeds higher than 140 or 150 m.p.h.

Effect of Size and of Reynolds Number

In a series of models geometrically similar but of graded sizes, study of the effect of size has in the past been difficult. First, there is interference between the model and the boundary of the stream, which for larger models distorts the forces, requires a theoretical correction and hampers the attainment of proper conclusions. In our tests, these wall-interference corrections were themselves under scrutiny. Secondly, the supporting means, either wire or spindle, reduces the test precision of small models more than that of large models, so that true size-effect is often hidden beneath accidental tare-effect. Thirdly, the models of a series are seldom truly similar, especially in the smaller sizes, because of defects in manufacture. To illustrate this, the case of a 6 x 36-in. Clark-Y airfoil-test is cited, in which, during a long test, a layer of dust accumulated on the model. At the end of the test, this almost negligible excrescence on the original wing-contour had noticeably affected the lift curve. The effect was remedied by wiping off the model. The thickness represented by the dust layer was less than the tolerance limits usual in model making. This is one, although not the chief, reason for adopting cylindrically cambered airfoils, inasmuch as these can be turned on a lathe and ground, if necessary, to secure true geometrical similarity.

After minimizing so far as possible the spurious effects mentioned, results were established as follows:

Effect of Size When the Speed Is Constant.—Fig. 8 shows, for the cylindrical airfoils, that increase of the size of the model at constant speed has an effect similar to, but not exactly the same as, increase of speed in dispersing the lift curves. If the law of dynamic similarity were to apply, doubling the size should produce the same

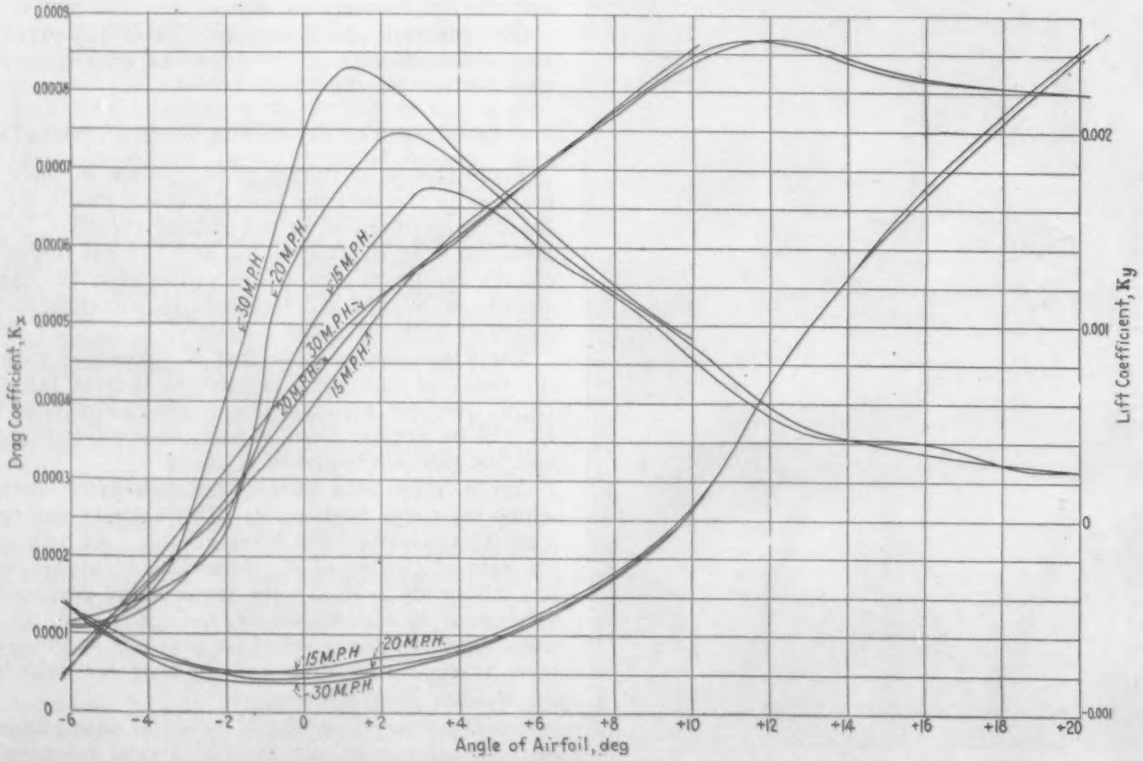

FIG. 5—EFFECT OF SPEED ON 6 x 36-IN. CONVENTIONAL THIN AIRFOIL

The Curves Show the Means of Erect and Inverted Runs. The Tests Were Made with the Duplex Straightener. The Lift Dispersion Is a Characteristic of the Airfoil and Entails a Departure from the v^2 Law. It Shows That at the Low-Drag Region of the Lift Curve a Special Scale-Correction Must Be Used

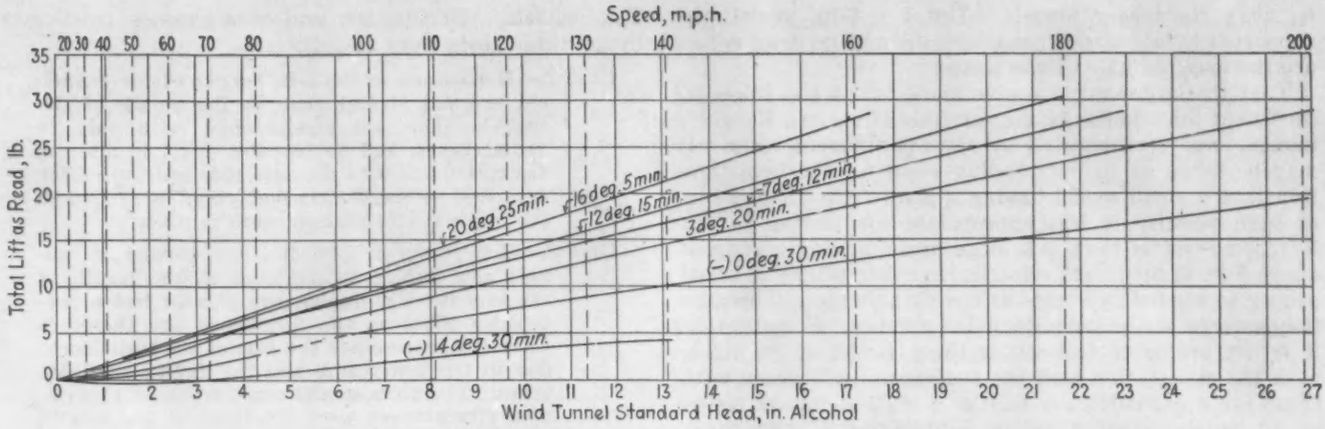
Speed, m.p.h.
Total Lift as Read, lb.
Wind Tunnel Standard Head, in. Alcohol
+20 deg. 25 min.
+16 deg. 5 min.
+12 deg. 15 min.
+7 deg. 12 min.
3 deg. 20 min.
(−) 0 deg. 30 min.
(−) 4 deg. 30 min.

FIG. 6—SPEED RUNS OF 3 x 18-IN. CYLINDRICALLY CAMBERED AIRFOIL

The Wire Balance and Honeycomb Were Used. All Factors Were Maintained Constant While the Speed Was Increased Progressively. Any Departure of the Curves from a Straight Line Represents Departure from the v^2 Law. The Curve for —4.5 Deg. Changes Its Sign at 70 M.P.H.

change as doubling the speed. Fig. 9 shows that the effect of size is less on the thin C-27 airfoil.

Effect of Size When the Reynolds Number Is Constant. —To satify the theoretical law of dynamic similarity, the Reynolds number should be the same for all the tests; that is, for such tests as these, where viscosity is constant, the product of size times velocity should be the same. This is the case in Fig. 10 for 0.15-camber cylindrical airfoils, where the 3 x 18-in. model was run at 60 m.p.h., the 4 x 24-in. at 45 m.p.h., the 5 x 30-in. at 36 m.p.h., the 6 x 36-in. at 30 m.p.h., the 7 x 42-in. at 25.71 m.p.h., and the 8 x 48-in. at 22.5 m.p.h. The polar diagrams for the three larger models, when corrected for wall interference by Prandtl's formula, lie reasonably well together, considering the sensitiveness of these airfoils. The small models show consistently a higher minimum K_x and a lower maximum K_y than the large models, although the Reynolds number is the same, and differ from one another more than do the large airfoils.

This high drag of the smaller models was made the subject of special tests and studies because the spindle and wire tare-forces for the small models are proportionally greater than for the large models and the curves therefore are less precise. After discounting the possibility of experimental error, the evidence is consistent that the 3 x 18-in. and 2 x 12-in. models have a higher

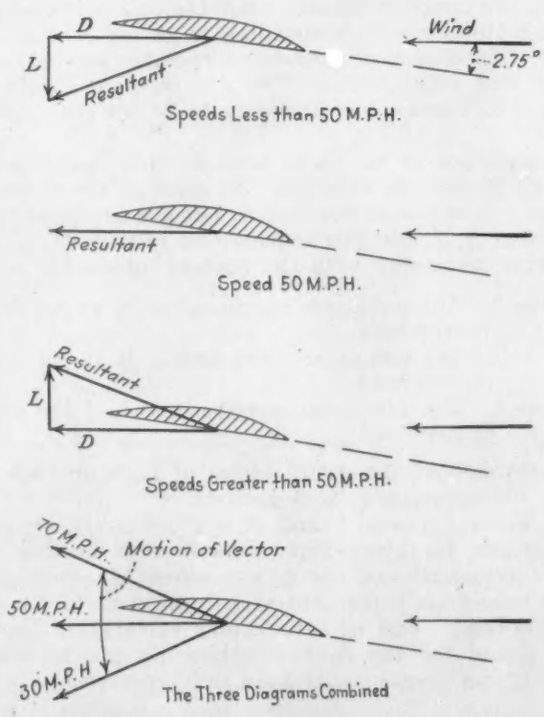

FIG. 7—EFFECT OF CHANGE OF SPEED FROM 30 TO 70 M.P.H.

At an Airfoil Zero-Lift Angle of —2.75 Deg., the Resultant Force-Vector Has a Progressive Continuous Upward Swing That Operates Chiefly on the Lift Rather than on the Profile Drag, Due Possibly to the Boundary Layer of the Airfoil

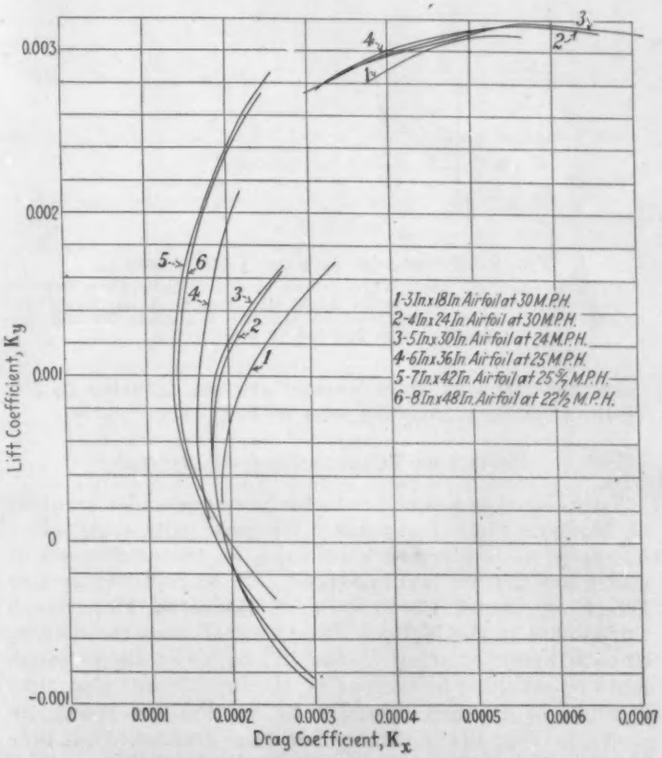
Lift Coefficient, K_y
Drag Coefficient, K_x
1-3 In x 18 In Airfoil at 30 M.P.H.
2-4 In x 24 In Airfoil at 30 M.P.H.
3-5 In x 30 In Airfoil at 24 M.P.H.
4-6 In x 36 In Airfoil at 25 M.P.H.
5-7 In x 42 In Airfoil at 25⅝ M.P.H.
6-8 In x 48 In Airfoil at 22½ M.P.H.

FIG. 8—EFFECT OF SIZE ON CYLINDRICAL CAMBERED AIRFOILS

Six Similar 0.15-Camber Cylindrical Airfoils Were Used at Approximately Constant Speed, with Honeycomb. Wall-Interference Corrections Are Applied to the Curves. The Curves Show that Increase of the Size of the Model at Constant Speed Has an Effect Similar to, but Not Exactly the Same as, Increase of Speed in Dispersing the Lift Curves

K_x than the larger models. The 1 x 6-in. model was supported by a guarded crank-spindle and its drag values are the least reliable of the series.

That the larger airfoils give more nearly the full-scale coefficient than do the smaller airfoils at a given Reynolds number was corroborated by several different tests. It may be taken as an outstanding result of the investigation that a small model having a span from 18 to 24-in. at high velocity is less appropriate for testing in our 5-ft. wind-tunnel than is a large model having a span of about 3 ft. at moderate velocity. In other words, it is not proper to regard two tests as comparable merely because they are run at the same Reynolds number. For example, it is not proper to test a 3 x 18-in. model at 80 m.p.h. with the expectation that the coefficients will agree with those for a geometrically similar 6 x 36-in. model tested at 40 m.p.h., even after wall-interference corrections have been applied.

Referring to the chart for the very thin C-27 series of airfoils, the polars lie reasonably well together, except for the 2 x 12-in. model, whose precision of test is the poorest of the series. The evidence agrees well with the 0.15-camber series; namely, that 6 x 36-in. airfoils, when

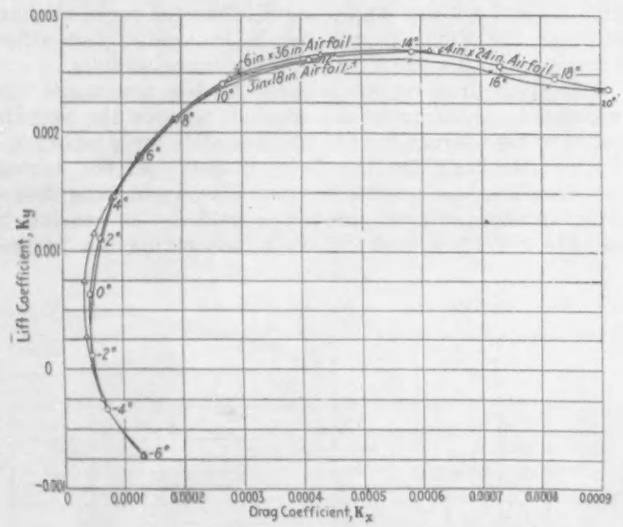

FIG. 9—EFFECT OF SIZE ON THIN AIRFOILS

Airfoils of the C-27 Type Were Tested on the Spindle-Type Balance with Honeycomb. The Curves Show the Means of the Erect and Inverted Runs at a Velocity of 30 M.P.H. Wall-Interference Corrections Are Applied to the Curves

corrected for wall interference, are not inferior to 3 x 18-in. airfoils, as may be seen in Fig. 11.

EFFECT OF TURBULENCE ON AIRFOILS

Turbulence as a variable factor has been under scrutiny at McCook Field for years. Its most noticeable effect has been, as is common knowledge, on the coefficients of maximum lift, or landing-speed. It was shown in The Effect on Model Coefficients of Reducing Honeycomb Turbulence in the McCook Field Tunnel[4], that the discontinuous break existing in the lift curve of thick wings could be retarded by increasing the turbulence; also, that it could be further retarded by raising the speed, as shown in Fig. 12. Evidence has been frequent that turbulence plays a less important role at the higher speeds.

Figs. 13 and 14 show how, at lower speeds, alternation of turbulence changes the polar curves for thick and for thin models. Honeycomb and straightener conditions in the three tests were as follows:

Case 1.—Honeycomb in the 5-ft. portion of the tunnel; old original straightener at the mouth of the tunnel. This old straightener, with only 16 radial vanes, had no readable effect in altering the turbulence, and the data obtained were often described as for "honeycomb only," even though the original straightener were in place

Case 2.—Honeycomb in 5-ft. diameter portion of tunnel; new duplex straightener at the mouth of the tunnel. The duplex straightener had a perceptible effect on the turbulence and therefore Case (2) represented the sum of the turbulences due to the honeycomb and the duplex straighteners. The purpose and construction of this duplex straightener were described in the Report on Wind-Tunnel Test No. 200, Serial No. 2636, on the Calibration Constant of McCook Field 5-ft. Wind-Tunnel with Honeycomb Removed and with New Straightener at Intake

Case 3.—Honeycomb was removed and only the duplex straightener at the intake was used. This duplex straightener had a large number of vanes so that no vortex of greater diameter than 2 in. could enter the plane of the intake of the wind-tunnel. The entrance air traversed these vanes at relatively low velocity, with relatively low energy-loss

It is necessary to define the use of the expression "turbulence" in this report. By turbulence is meant the network of low-energy swirls that leave the trailing edge of the honeycomb-cell surfaces and by their below-normal energy-head, as measured by an impact, or pitot, tube, the amount of energy lost when the air traverses the honeycomb. As a measure of this turbulence, it is sufficient to determine the pressure drop across the honeycomb. In terms of velocity head, the original honeycomb gave a turbulence corresponding to 12 per cent velocity-head. The duplex-straightener turbulence was only about 2 per cent velocity-head. The two together should then have a turbulence corresponding to 14 per cent velocity-head.

Comparison of the three cases of turbulence disclosed a very interesting situation. In general, the curves for Cases 1, 2 and 3 do not overlie, but are arranged in the sequence, 1, 2, 3. The sequence of relative turbulence, however, beginning with the highest turbulence is:

Case 2.—The turbulence corresponding to 14 per cent velocity-head

Case 1.—The turbulence corresponding to 12 per cent velocity-head

Case 3.—The turbulence corresponding to 2 per cent velocity-head

Yet, throughout the entire series of tests on both airfoils, the sequence 1, 2, 3 persists.

In general Cases 1 and 2 are relatively close together and far away from Case 3, thus making general conclusions easy as to the effect of altering the turbulence from 2 per cent velocity-head to 12 per cent velocity-head. But no satisfactory explanation has yet been found for the effect of changing the turbulence from 12 per cent velocity-head to 14 per cent velocity-head.

The first and obvious explanation of the effect was that some unexpected error had entered the work and had escaped detection; but no error could be found. The usual tare lift and drag corrections are of no significance here, since the methods of support and the corresponding

[4] See Airplane Department Memorandum No. 821.

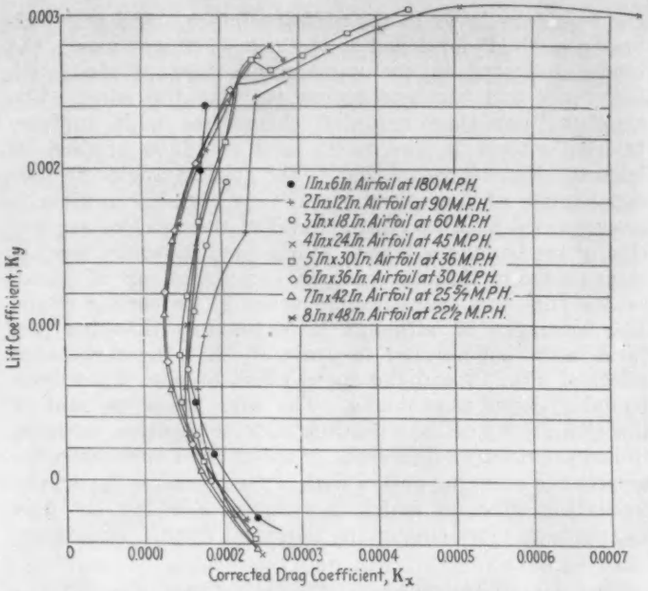
Lift Coefficient, Ky
Corrected Drag Coefficient, Kx
1 In. x 6 In. Airfoil at 180 M.P.H.
2 In. x 12 In. Airfoil at 90 M.P.H.
3 In. x 18 In. Airfoil at 60 M.P.H.
4 In. x 24 In. Airfoil at 45 M.P.H.
5 In. x 30 In. Airfoil at 36 M.P.H.
6 In. x 36 In. Airfoil at 30 M.P.H.
7 In. x 42 In. Airfoil at 25 5/7 M.P.H.
8 In. x 48 In. Airfoil at 22 1/2 M.P.H.

FIG. 10—JOINT EFFECT OF SIZE AND VELOCITY ON CAMBERED AIRFOILS HAVING THE SAME REYNOLDS NUMBER

The Curves Are for Eight Geometrically Similar Cylindrically Cambered Airfoils Having the Reynolds Number, $lv = 22$ Ft.²/Sec. The Honeycomb Was Used. Wall-Interference Corrections Are Applied to the Curves

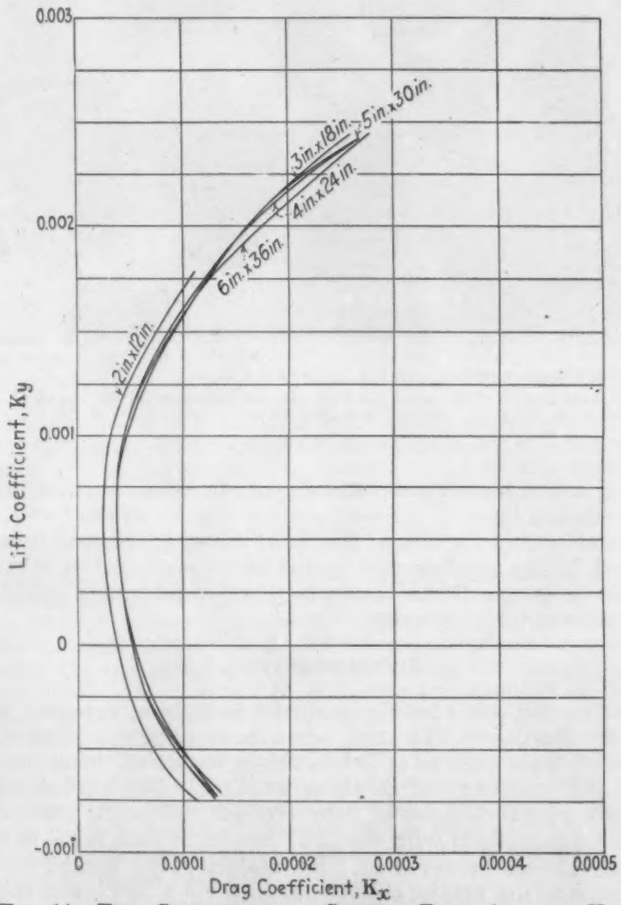

FIG. 11—FIVE GEOMETRICALLY SIMILAR THIN AIRFOILS HAVING THE SAME REYNOLDS NUMBER

The Reynolds Number Was the Same as for Fig. 10. The Airfoil Sizes and the Speeds of the Runs Were as Follows: 2 x 12-In., 90 M.P.H.; 3 x 18-In., 60 M.P.H.; 4 x 24-In., 45 M.P.H.; 5 x 30-In., 36 M.P.H.; 6 x 36-In., 30 M.P.H. The Curves Are the Means of Erect and Inverted Runs with Honeycomb and Are Corrected for Wall Interference. The Curve for the 6 x 36-In. Airfoil Is Shown To Be Not Inferior to the Curve for the 3 x 18-In. Airfoil

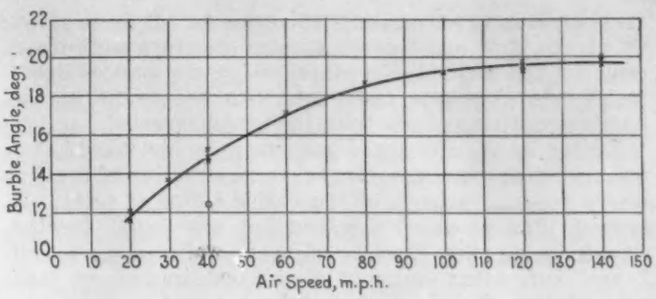

FIG. 12—EFFECT OF SPEED ON LANDING ANGLE OF 1/50-SCALE AIRPLANE MODEL

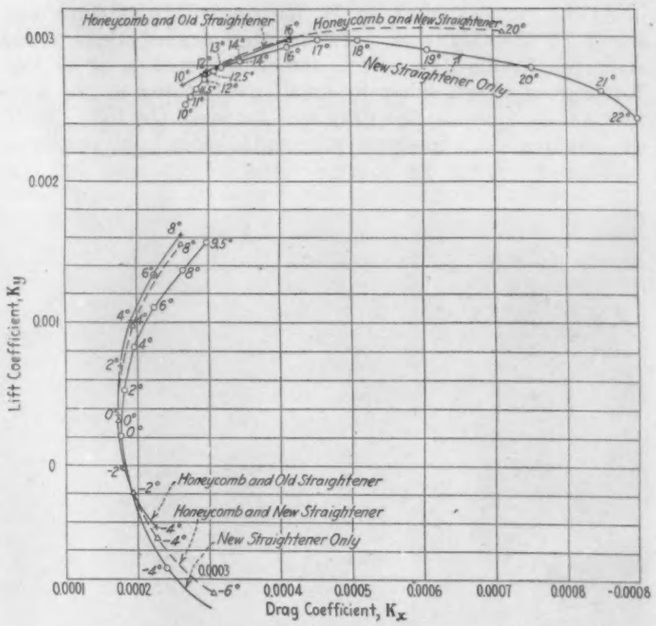

FIG. 13—EFFECT OF TURBULENCE ON CYLINDRICALLY CAMBERED AIRFOIL

Tests Were Run on a 3 x 18-In. 0.15-Camber Cylindrical Airfoil, and the Curves Are the Means of Erect and Inverted Runs at a Speed of 40 M.P.H. In Case (1) the Turbulence Condition Was That Due to Honeycomb and the Old Straightener; in Case (2) to the Honeycomb and the New Straightener Jointly; and in Case (3) to the New Duplex Straightener Only

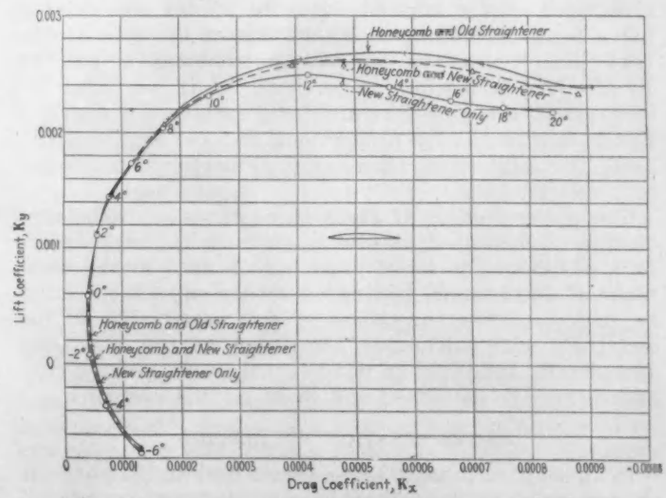

FIG. 14—EFFECT OF TURBULENCE ON THIN AIRFOIL

Runs Were Made with a 3 x 18-In. C-27 Airfoil under the Same Conditions as in Fig. 12. Comparison of the Two Sets of Curves Shows that, at the Lower Speeds, Alteration of Turbulence Changes the Polar Curves for Thick and Thin Models

tare-corrections were exactly the same for all three cases. Of course, flow and balance alignment-errors were overcome by the method of test on which we standardized; namely, by duplicate tests, one with the model in the normal position and one with the model inverted.

Errors in velocity could not creep in undetected, for pressure-drop readings were taken as a matter of routine where needed, throughout the entire series of tests. It is true that no velocity calibration was made for the Case-2 tests, the Case-1 calibration being corrected 2 per cent, after study of Case-3 calibration, to take care of Case 2. No fault has been found in this procedure. Finally, a pure velocity-error would at once be shown by virtue of the fact that L/D is independent of small changes in velocity.

At the suggestion of Dr. W. Klemperer, an attempt was made to identify this peculiar sequence of the curves with the Knolle-Betz effect, sometimes spoken of as the Katzmayer effect, whereby small oscillations in the air-flow act to decrease the drag and increase the lift. Such an explanation, however, demands secondary assumptions such as, for example, that the duplex straightener has a function tending to oppose that of the honeycomb; that thus, when the honeycomb produces a positive Knolle-Betz oscillation proportional to 12 per cent velocity-head, the duplex straightener produces a negative Knolle-Betz oscillation proportional to 2 per cent velocity-head, the joint effect then being proportional to 10 per cent velocity-head.

The evident effect of these three types of turbulence on thin conventional, as well as on thick cylindrical, airfoils is thought to be of great significance to the technique of wind-tunnel testing. Further experiment must be made to define the causes of this peculiarity, to the end that, with advancing knowledge of the trickeries and pitfalls obtaining in wind-tunnel work, greater confidence may be developed and these pitfalls overcome.

Interpretation of Results

In an attempt to trace these effects back to the physical phenomena that cause them, visual study was made of the boundary layer at the airfoil surface. For this purpose a method developed at McCook Field was used. The model, mounted in the wind-tunnel, was painted with lampblack and kerosene before starting the wind. The air-flow lines then recorded themselves with surface friction effects in the paint, and could be studied at leisure. Fig. 15 shows that at the critical angle the sudden change of flow from low-lift to high-lift regime is accompanied by a rearward travel of the point of separation of the boundary layer. It has been shown by balance measurements that increase of turbulence, or of speed, causes this flow transition to occur at an earlier angle. The inference is, although unfortunately flow-line pictures were not secured to prove it, that the turbulence effect of Fig. 13 and the speed effect of Fig. 4 are both boundary-layer phenomena. The same could be said of the change of the lift from negative to positive, as mentioned previously. Increases of speed or of turbulence intensify the scouring action within the boundary layer, the insulating effect of which is reduced, allowing the flow to approach more closely the potential form. The scouring action has its greatest influence in cases in which the boundary layer is the least stable; that is, at the burble-point of thin airfoils, at the flight angles of thick airfoils, and in the air-flow past struts and fuselages; in other words, in exactly the cases in which wind-tunnel model-tests are least reliable.

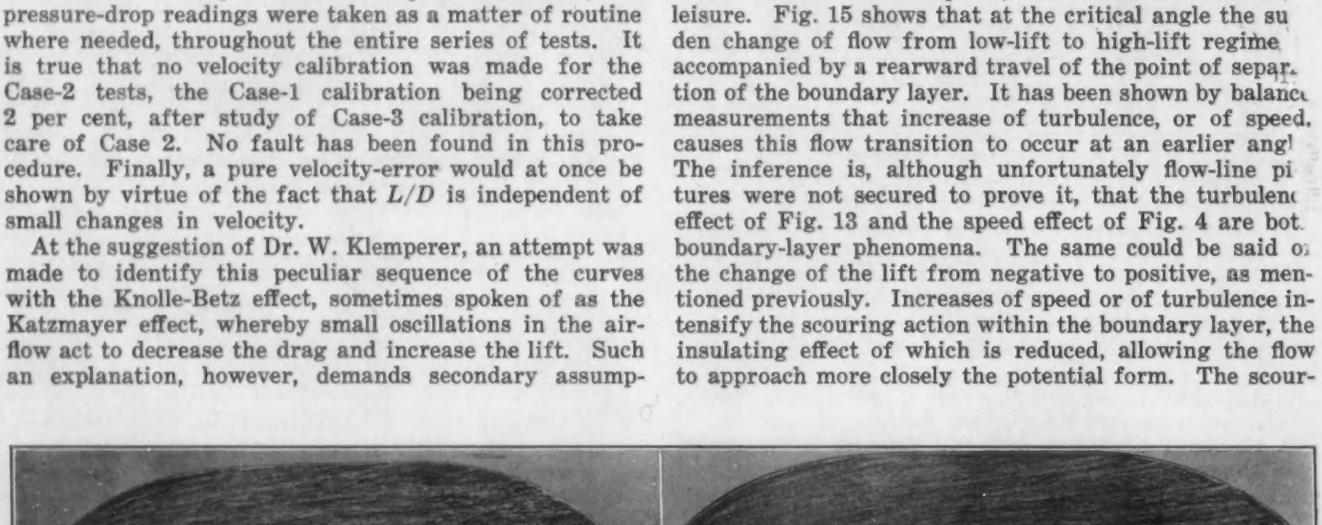

Fig. 15—Flow Lines on Cylindrically Cambered Airfoil at 8.0 and 10.5 Deg.

The Flow Lines Extend from Left to Right. Those in the Left View, with the Airfoil at an 8.0-Deg. Angle, Separate from the Airfoil at 6/10 of the Chord, whereas the Flow in the Right View, with the Airfoil at a 10.5-Deg. Angle, Does Not Separate until 8/10 of the Chord

Recommendations

The McCook Field tests should have been extended a little further. The final step, unfortunately omitted, would have been to ascertain the influence of turbulence at high speeds; that is, above 80 m.p.h. Our high-speed tests with turbulence in 1925 were not sufficiently precise to compare them with our 1927 non-turbulence tests, and they should be repeated. By replacing the honeycomb and securing precise coefficients on the 3 x 18-in. and the 6 x 36-in. cylindrical airfoils, the teachings of Fig. 13 could be extended. They should also be verified by retesting at high velocities the thin airfold shown in Fig. 14 under both turbulent and non-turbulent flow-conditions, the thin airfoils not having been given high-speed wire-balance runs. Furthermore, the 8 x 48-in. cylin-

[8] See The Journal, May, 1927, p. 575; also Visual Study of the Flow Discontinuity on a 6 x 18-In. 0.15-Camber Airfoil, Airplane Department Memorandum No. 748.

drically cambered airfoil should be given high-speed precise tests on the wire balance under both flow conditions to find out whether the influence of turbulence persists in the large as in the small models.

Pending such corroboratory tests, the evidence points the use of large tunnels at speeds over 100 m.p.h. as means of overcoming the influence of turbulence. We ve shown, in summary, that for a 3 x 18-in. cylindrical irfoil, as in Fig. 4, only the curves above 100 m.p.h., nd for a 6 x 36-in. cylindrical airfoil the curves above 80 m.p.h., lie safely outside the region of dispersion. We have shown also that, in general, large models give more reliable results than small models.

The present tendency in wind-tunnels is toward larger size and higher speed. The smaller sizes, in which the variable factors discussed above are most troublesome, are obsolescent. But solution of the foregoing problems cannot be waived on the ground that our newer tunnels are ideal. The variable factors so troublesome in the smaller tunnels will persist in the larger tunnels, though in less degree, and standardization of our larger tunnels must take into account all these variable factors.

Motorcoach Influence on Electric Cars

A NOTEWORTHY break from precedent in electric-car body-design has been made recently by the Springfield Street Railway Co. The most striking item is the close resemblance to automotive equipment, with its single-pane windows, side panels resembling those on motorcoach bodies, sloping windshields, visor and automobile-type bumpers. The side panels extend much lower than is customary on present car bodies. This covers much of the unsightly equipment under the car and helps to muffle noise emanating from the trucks. The single-pane windows give a remarkably clean and pleasing appearance to the exterior of the car. In addition, they give unobstructed vision from the interior, as well as an appearance from within that may best be described as having the "dignity of simplicity." The front window has been enlarged to the proportions of the motorcoach windshield and slopes inwardly toward the top. This feature helps to give to the front the desired tapered appearance and prevents glare of lights in the operator's eyes at night. The inclusion of a visor over the windshield is also a highly desirable feature. The whole design, lending itself nicely to stream-line painting, conveys the idea of up-to-the-minute design. It is not expected that this is the ultimate design of electric cars, but it surely is a commendable attempt at improvement.

There is a distinct trend away from the old-style slat-covered floor. In addition to the linoleum, rubber, and similar types of floor covering, attention is called to composition floorings, which are applied in a plastic state with a trowel. Such a type of flooring lends itself readily to the addition of cove edging, with consequent easier sweeping of corners. Such a floor may be readily flushed with hose and water without fear of damage to the body or equipment.

Stream-Line Principles Followed

Stream-line painting is much in vogue at present and it is contended that its application to cars will do much to improve their appearance from an artistic standpoint, giving them a modish, uptodate air. What are the principles to be applied to car painting to give them a long, low, speedy appearance? The first is that of breaking-up the side of the car into two or more bands, instead of having it painted one solid color. This principle may be carried even further by the use of additional narrow bands. The second principle is the avoidance of vertical lines and bands, particularly of a dark color. The third principle is to create tapered ends and, in the case of a single-ended car, to make the front end look as if it were intended to be the front end instead of a duplicate of the rear end.

Comfortable Seats and Wider Windows

The adoption of a strictly high-grade seat is recommended for both city and interurban service. The term is intended to include a seat of the deep upholstered type, with a spring or yielding back. It is recommended that the maximum height of the cushion be 17½ in. above the floor. There is a marked trend toward individuality in seat design; that is, to make double seats resemble two seats. An example of this is the bucket-type seat. The consensus of opinion is that the provision of better seats is an entirely justifiable expenditure and attracts added patronage of sufficient volume to make it a paying venture.

It is recommended that, in the selection of seat covering, attention be given to the adoption of material that in texture and color will convey the impression of being uptodate. A black leather or imitation leather is less desirable than the newer shades which are not so somber and which will not show dust so much. In the textile coverings, colors should be modern and of the neutral tints which convey a restful feeling to the passenger.

Almost universal practice in electric-car construction is to place the seats on the same centers as the car posts, to provide one entire window to each seat. In motorcoach-body construction this rule is not adhered to rigidly and the seats are spaced as desired, irrespective of the distance between posts. This has been accomplished without serious adverse criticism and establishes a precedent that may be followed in electric-car construction. It also offers a suggestion for bettering the appearance of cars by the use of wider windows than those used at present.

Speed, Quietness and Comfort Necessary

Next in importance to seats in the furnishing of a comfortable ride is the item of springs, and the attendant mounting details which cause the car body to ride well or poorly. There is need for study and research to improve riding-qualities. Verdict on this quality should be based, not upon personal opinion, but upon scientific study with the assistance of a recording seismograph.

Undoubtedly, quiet-operating cars have a high ride-sales value, and it is of prime importance that, in the handling of the cars, smooth starting and stopping be practised. Car speed is to be given first place in consideration of the passengers' needs. No single factor is more important in creating a desire in passengers to avail themselves of a transportation service.

Recently a new type of car truck has been developed using a high-speed motor mounted on the truck entirely independent of the car axle. This introduces a new combination of conditions which, if taken full advantage of, may result in a lower car floor.

The subject of car convenience, comfort and appearance is one of the most important questions before the equipment men today, as it embodies all of the essentials which go to make successful the operation of a property, so far as cars are concerned. Unless these features are given proper consideration, the ride is not a salable commodity. The need, therefore, is to furnish a vehicle with the air of luxury about it which will create a desire in the public to ride in it in preference to the private automobile.—From report of Rolling Stock Special Committee of the American Electric Railway Engineering Association.

Supercharged Engine Performance, Calculated and Actual

By Opie Chenoweth[1]

Aeronautic Meeting Paper *Illustrated with* Charts

A method of predicting the power output of a given aircraft engine equipped with a direct gear-driven centrifugal supercharger is outlined. The calculations are based on the fundamental assumptions common to internal-combustion engineering.

Three superchargers of different ratings are considered for the purpose of selecting the one giving the best all-round performance. Considerations of weight, compactness, mechanical reliability, simplicity and general arrangement enter into the selection of the best all-round rating.

The effect of superchargers of various ratings on engine power-output, as well as the effect of various factors on engine performance, is shown by curves.

Tests of a supercharged Curtiss D-12 engine were conducted in the altitude chamber of the Bureau of Standards and the results of this test were compared with the calculated results obtained by the method outlined.

Conclusions reached are that, for all-round performance to a definite altitude, an intermediate supercharger rating should be selected, and that the performance of engines equipped with direct-driven centrifugal superchargers can be predicted with a fair degree of accuracy by the methods outlined.

FOR several years the Air Corps has been interested in the supercharging of airplane engines. In connection with the development of various types of supercharger, a study of the probable performance of a supercharged engine was undertaken under the direction of E. T. Jones, who at that time was chief of the powerplant section of the Engineering Division. As a check on the calculated performance, a Curtiss D-12 engine was equipped with a supercharger and placed in the altitude chamber of the Bureau of Standards, where performance data were obtained.

The object of this paper is to outline a method of predicting the horsepower available at all altitudes from an engine equipped with a direct-driven geared centrifugal supercharger, to compare the results that can be expected from the same engine when equipped with superchargers of different altitude ratings, and to present an actual performance check on one of the engine-supercharger combinations.

Although a gear-driven supercharger is capable of maintaining sea-level pressure in the intake manifold up to a certain maximum altitude, the horsepower available from the engine is not constant up to this point. Several factors contribute to a reduction in power at the lesser altitudes even when constant inlet-pressure is maintained by the supercharger. Chief among these are the horsepower required to drive the supercharger, the reduction in charge density due to the heating of the air in the supercharger, variation in the mean effective pressure due to the difference between the exhaust pressure and the intake pressure, and variations in the speed of the engine due to variation in the propeller characteristics with density, airplane altitude and speed. During climb, the last factor has a far greater effect than any of those mentioned but the influence of the others is by no means negligible. Above the altitude corresponding to the supercharger rating, the pressure in the intake manifold falls off, introducing another factor that tends to reduce the power output of the engine. In this region, the behavior of a supercharged engine is similar to that of an unsupercharged engine. As a result of these factors, the supercharged engine, as operated in the airplane, delivers considerably less power than the unsupercharged engine at sea-level. As the altitude is increased, the power delivered by the engine increases until the point is reached at which the supercharger can no longer maintain sea-level pressure in the intake manifold. From this point on the power decreases.

The influence of all the factors mentioned above as affecting the power developed by the engine at altitudes below the rated altitude of the supercharger increases as the altitude rating of the supercharger is increased; thus, an engine equipped with a high-altitude supercharger will deliver considerably less power at sea-level than one equipped with a supercharger of lower rating. Since the airplane is required to operate at all levels from sea-level up to possibly 25,000 ft., the best average operation will not be secured with a supercharger designed to supercharge fully up to the maximum altitude. An airplane equipped with such a supercharger would be at a distinct disadvantage at the lesser altitudes, hence it appears probable that the most desirable gear-driven centrifugal supercharger will have an intermediate rating that will not penalize the airplane too severely at low altitudes and, at the same time, will give a substantial increase in performance at greater altitudes. The selection of the most desirable rating for all-round performance cannot be reduced to a mathematical basis, since no mathematical expression for all-round performance exists; an intelligent selection will, however, be greatly assisted by the preparation of curves indicating the power available at all altitudes with superchargers of various ratings.

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[1] Jun. S.A.E.—Carbureter development engineer, aircraft power plants section, materiel division, Air Corps, Wright Field, Dayton, Ohio.

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liability, simplicity and general arrangement also enter into the selection of the best all-round supercharger rating. The Materiel Division has experimented with two types of gear-driven centrifugal supercharger, a 20,000-ft. supercharger having an air-cooler and the carbureters on the pressure side of the supercharger, and a 7500-ft. supercharger having the carbureter on the suction side of the supercharger without an air-cooler. Both these types have been installed in airplanes and their effect on the airplane performance has been determined. Neither has proved sufficiently reliable from the mechanical point of view to be considered a satisfactory solution of the problem. On the other hand, very encouraging results have been obtained and, by combining the best features of both types, a very satisfactory and reliable supercharger apparently can be developed.

Development of Suction Type Desirable

The general arrangement of the 7500-ft. supercharger is very attractive from the point of view of carburetion, accessibility, simplicity and compactness. Although the use of an air-cooler results in an appreciable gain in power output, the weight, complication and frontal area are greatly increased. The combination of an air-cooler with the carbureter on the suction side of the supercharger is not attractive, since the temperature drop resulting from vaporization of the fuel greatly reduces the temperature head available for cooling, thus necessitating a larger air-cooler. Furthermore, the air-cooler results in a great increase in the volume of the induction system which increases the risk of difficulty from backfiring. The suction carbureter has proved so satisfactory from the point of view of simplicity, compactness and fuel economy that the development of this type seems desirable rather than that of another type which makes use of an air-cooler with carbureters on the pressure side of the supercharger.

The chief difficulty in the development of a satisfactory gear-driven centrifugal supercharger lies in providing a light high-speed gear-train of sufficient strength to withstand the sudden acceleration imposed upon the drive by crankshaft torsional-vibration. This difficulty increases as the supercharger altitude rating is increased, as a higher rating requires an impeller having either a larger diameter or a higher speed. In either case, the effective inertia of the impeller is increased, thus increasing the acceleration loads on the gear-train.

The problem is to determine the altitude rating that is most desirable from considerations of power output and airplane performance throughout the range of altitudes likely to be encountered in service. These data, together with the mechanical problems involved, must be considered in determining the altitude rating to be selected for further development of this type of supercharger.

Analysis of the Problem

When this study was made, no altitude-chamber tests of supercharged engines were available, making it necessary to rely on calculations for data as to the power available from supercharged engines under various conditions of flight. This required the development of a method of computing the power output of a known engine and supercharger combination under any conditions of altitude and crankshaft speed. Curves could then be plotted of power output at various altitudes and crankshaft speeds for superchargers of different ratings. These curves, combined with curves of propeller speeds at various altitudes, make possible the determination of the power available at all altitudes, either in climbing or in level flight, and thus allow an intelligent estimate of the airplane performance under all conditions encountered in service.

To ascertain the power output of a specific engine and supercharger combination at any given altitude and speed, it is necessary to determine, first, the characteristics of the supercharger. Having these, the horsepower required to drive the supercharger, and the temperature and pressure rise through the supercharger, can be determined. The conditions in the inlet and exhaust manifolds are then determined, as well as the power diverted to driving the supercharger. From these data, the power output of the engine can be calculated on the basis of reasonable assumptions as to the effect of intake and exhaust-manifold conditions on the power developed.

The various assumptions involved in the calculation of supercharger and engine performance and the reasons for their adoption are listed as follows:

The Supercharger

(1) The compression in the supercharger follows the polytropic law, that is $PV^n = \text{Constant}$. It is general engineering practice to assume this law to hold in dealing with the performance of centrifugal compressors

(2) The supercharger efficiency will be 70 per cent under the rated conditions. Consideration of efficiency tests of several superchargers, together with the results obtained by the General Electric Co. with numerous types of centrifugal compressor, leads to the conclusion that an efficiency of 70 per cent can be expected

(3) Small variations from rated conditions do not affect the supercharger efficiency. The characteristic efficiency curves of centrifugal compressors usually show very slight variations in efficiency for small deviations from rated conditions. The rated condition of a centrifugal compressor is fixed by the ratio of cubic feet of air entering the compressor to the speed of the impeller. As operated on an engine at full throttle, the quantity of air entering the engine tends to vary directly as the crankshaft speed, hence, throughout the range of conditions considered, the ratio of the entering volume to the speed remains practically constant. Constant efficiency can therefore be assumed

(4) The temperature drop due to evaporation in the supercharger does not affect the pressure rise or the efficiency of the supercharger. This assumption is certainly not in accord with the facts but is necessary, as data on the degree of evaporation taking place are lacking

(5) The power input to the supercharger varies directly as the cube of the speed and as the density of the entering air. This is in accord with the general theory applying to centrifugal compressors

(6) At constant speed, the temperature rise through the supercharger is constant. This is in accord with the general theory applying to centrifugal compressors

(7) The air-temperature rise in the supercharger varies directly as the square of the speed. This is in accord with the general theory applying to centrifugal compressors

(8) Radiation from the supercharger and the intake manifolds may be neglected. In the type of installation considered, the supercharger cas-

ing and the intake manifolds are well protected from air blasts, hence this assumption seems sound

(9) The supercharger rating is defined by the maximum altitude at which sea-level pressure can be maintained in the intake manifold. This assumption is purely a matter of definition and requires no discussion

(10) Up to the rated altitude, the supercharger control is so manipulated as to maintain sea-level pressure in the intake manifold. This is in accord with the usual methods of supercharger control employed to date

(11) At the rated altitude, the pressure drop through the carbureter is 1.5 in. of mercury and this drop varies as the density and the square of the volume of the entering air. The carbureter drop is entirely dependent upon the restriction that the carbureter offers to the air-flow. The value of 1.5 in. of mercury is fairly representative of carbureters now being used

The Engine

(12) The engine may be operated with sea-level pressure (29.92 in. of mercury) in the intake manifold without encountering preignition or detonation. The fact that both the intake pressure and the temperature are higher than is the case in normal operation would tend to indicate that this assumption is unsound. Actual flight tests have demonstrated, however, that no trouble from preignition or detonation arises when sea-level pressure is maintained in the intake manifold

(13) Variations in the temperature drop caused by evaporation of the fuel have no effect on the total weight of the charge entering the cylinder. This assumption must be considered in connection with the next assumption

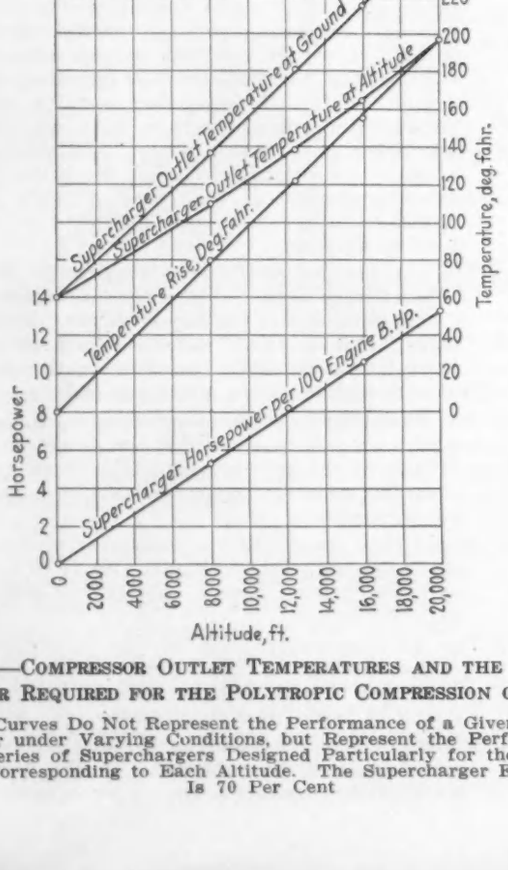

FIG. 1—COMPRESSOR OUTLET TEMPERATURES AND THE HORSEPOWER REQUIRED FOR THE POLYTROPIC COMPRESSION OF AIR

These Curves Do Not Represent the Performance of a Given Supercharger under Varying Conditions, but Represent the Performance of a Series of Superchargers Designed Particularly for the Conditions Corresponding to Each Altitude. The Supercharger Efficiency Is 70 Per Cent

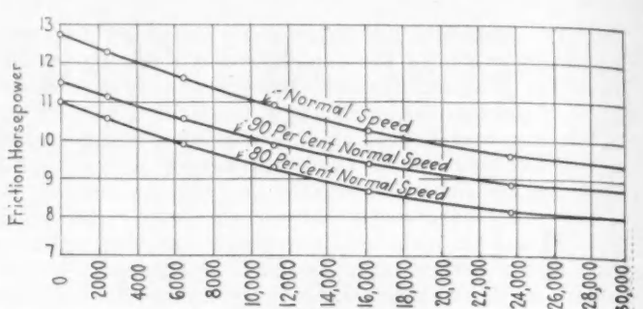

FIG. 2—FRICTION HORSEPOWER OF CURTISS D-12 ENGINE AT VARIOUS ALTITUDES

These Curves Are Based on Bureau of Standards Altitude-Chamber Data

(14) The indicated mean effective pressure varies inversely as the square root of the absolute temperature in the intake manifold. In computing the influence of temperature on the mean effective pressure developed, it is assumed that no drop in temperature due to the vaporization of the fuel occurs. The increase in volume due to vaporizing the fuel is offset by the decrease in volume caused by cooling the air. This tends toward a substantially constant charge-density regardless of the amount of vaporization. Although the validity of this assumption has not been analyzed thoroughly, numerous dynamometer calibrations of supercharged engines indicate that it is substantially correct. The square-root correction is in accord with the recommendations of the Bureau of Standards

(15) With normal exhaust-pressure, the indicated mean effective pressure varies directly as the pressure in the intake manifold. This assumption is in accord with the customary practice in computing corrected mean effective pressure and has been substantiated by numerous tests conducted by the Bureau of Standards

(16) When operating with an induction pressure in excess of the exhaust pressure, the normal indicated mean effective pressure is increased by an amount equal to the difference between the intake pressure and the exhaust pressure. This assumption is in accord with theory and has been substantiated by tests conducted by the Bureau of Standards

(17) When operating with an intake-manifold pressure in excess of the exhaust-manifold pressure, the weight of charge entering the cylinder is increased in per cent as the product of the clearance space in per cent of piston-displacement and the ratio of the pressure difference to the intake pressure. It is further assumed that the power developed is increased in direct proportion to the increased weight of the charge. The intake pressure, being higher than the exhaust pressure, the incoming charge compresses the residual exhaust, thus allowing a larger quantity of charge to enter the cylinder. Since the expansion ratio is not affected by this action, the power developed apparently should increase in direct proportion to the weight of the charge

(18) For given induction and exhaust conditions, the indicated mean effective pressure is independent of the crankshaft speed. This assumption probably is not strictly correct. The variation

in the indicated mean effective pressure with the crankshaft speed of a normal engine depends upon both the valve and the manifold losses. In the case of the supercharged engine, we have assumed the manifold pressure to be constant, hence the valve losses affect only the volumetric efficiency of the engine. This tends to reduce the drop in the indicated mean effective pressure with speed

(19) A well-designed engine consumes 0.122 lb. of air per b.-hp. per min. This figure is based on the Bureau of Standards tests of the Curtiss D-12 engine and has been checked by various methods. The value assumed is considered a good average value for modern engines. It should be noted that inaccuracies in this figure have only a small effect on the calculations, since only the horsepower input of the supercharger is changed

(20) The mechanical efficiency of a well-designed engine is 88.7 per cent at the rated speed and load. This assumption is based on a Bureau of Standards test of a Curtiss D-12 engine

(21) The friction-horsepower results given in the Bureau of Standards report on altitude tests of the Curtiss D-12 engine may be applied to this computation. Friction-horsepower figures are unsatisfactory at best, and the values referred to seem to be as reliable as any that can be secured

Basis of the Calculations

The three preceding assumptions Nos. 19, 20 and 21, might be grouped into the single assumption that the Curtiss D-12 engine is representative of modern water-cooled aircraft engines; therefore the characteristics of this engine will be used throughout as a basis of the calculations. In computing the desired values on the basis of the foregoing assumptions, all calculations are made for a hypothetical engine having a normal sea-level output of 100 hp. and all other characteristics similar to those of the Curtiss D-12 engine.

Curves of supercharger input-horsepower and of temperature rise corresponding to various altitude-ratings were first prepared. The supercharger inlet-pressure is equal to the pressure corresponding to the rated altitudes selected minus the carbureter drop. The ratio of this pressure to the sea-level atmospheric-pressure gives the compression ratio of the supercharger, and this value, together with the assumed efficiency, makes possible the calculation of the temperature rise. The horsepower input can also be calculated from the compression ratio, the initial temperature and the assumed weight of air. Having the temperature rise, the manifold temperatures at sea-level and at the rated altitude can be obtained by adding the temperature rise to the corresponding atmospheric temperature.

The results of these calculations are shown graphically in Fig. 1. In connection with this curve, it should be noted carefully that this does not represent the performance of a given supercharger under varying conditions, but represents the performance of a series of superchargers designed specially for the conditions corresponding to each altitude. The curves of manifold temperature indicate that this factor probably will definitely limit the maximum supercharger rating that may be selected. The temperature corresponding to the 12,500-ft. supercharger-rating seems to be the highest that can safely be employed in engines of the type considered, hence this value was selected for one of the supercharger ratings to be considered. A lower rating of 8000 ft.

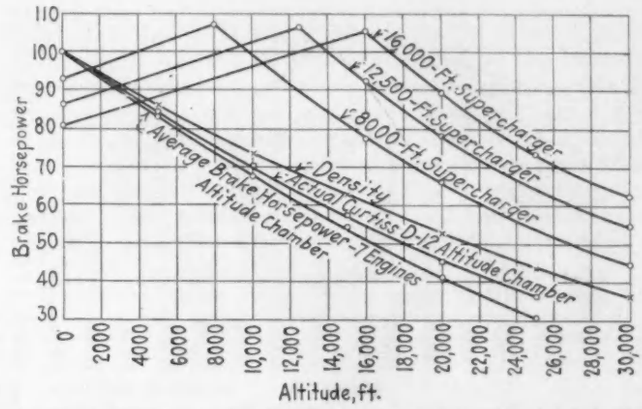

FIG. 3—VARIATION OF BRAKE HORSEPOWER WITH ALTITUDE AT CONSTANT ENGINE-SPEED

The Curves Are for 8000, 12,500 and 16,000-Ft. Superchargers without Intercoolers. For Purposes of Comparison, Curves Are also Given That Indicate the Variation of Density with Altitude, Bureau of Standards Results of Altitude-Chamber Tests of the Curtiss D-12 Engine, and a Curve Representing the Average of Seven Bureau of Standards Altitude-Chamber Tests of Representative Aircraft-Engines

was taken for the purpose of comparison and, to make the comparison more complete, a higher rating of 16,000 ft. was also selected, although this rating is probably impractical due to the high temperature-rise involved.

Variation in Horsepower with Altitude

Having selected three ratings for consideration, curves were prepared showing the variation in horsepower with altitude of an engine equipped with superchargers of these ratings. In making these calculations, the atmospheric pressure and temperature at altitude were determined from standard curves, the carbureter drop was computed for conditions above the rated altitude on the basis of the assumptions mentioned, and the temperature rise through the supercharger was taken from the curve of supercharger characteristics, Fig. 1. The supercharger inlet-temperature and pressure were then determined, the inlet temperature being equal to the corresponding atmospheric temperature, and the inlet pressure being equal to the atmospheric pressure minus the carbureter drop. The compression ratio of the supercharger was then computed from the known

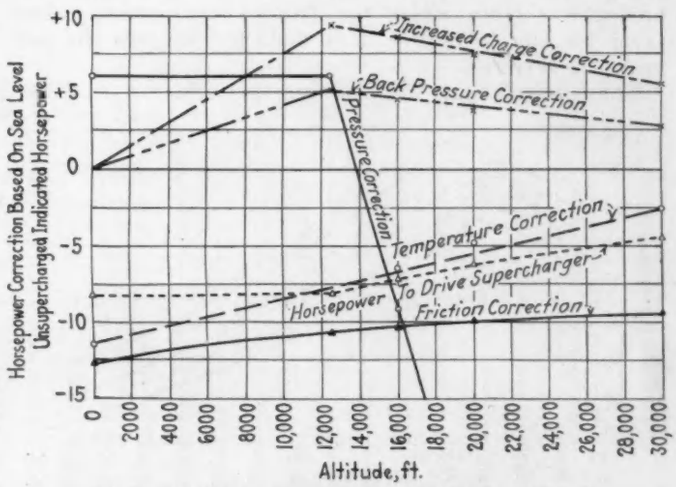

FIG. 4—CORRECTIONS FOR SUPERCHARGED ENGINE

This Is Based on Unsupercharged Ground-Level Indicated Horsepower, a 12,500-Ft. Supercharger Running at Normal Speed without Use of an Intercooler. The Curves Were Prepared To Show the Magnitude and Variation with Altitude of Each of the Correction Factors. The Values Shown Are Taken from Table 1, Which Gives the Figures for the 12,500-Ft. Supercharger at Normal Speed

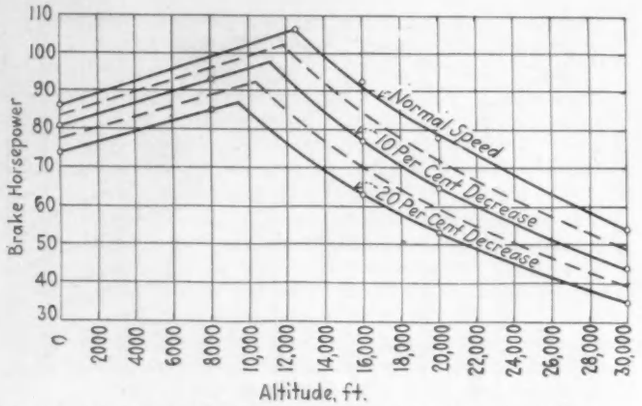

FIG. 5—EFFECT OF CHANGE OF SPEED UPON ENGINE PERFORMANCE WITH 8000-FT. SUPERCHARGER AND NO INTERCOOLER

In Computing the Power Output at Reduced Speed, It Was Necessary To Compute New Values of the Temperature Rise, the Horsepower Input, and the Pressure Ratio of the Supercharger, Since All These Depend upon the Crankshaft Speed

temperature-rise, and the initial temperature and the manifold pressure were obtained. The supercharger input-horsepower was next computed by taking the horsepower input at the rated altitude from the supercharger characteristic curve, Fig. 1, and reducing this value in proportion to the inlet density. It should be noted that, for altitudes below the supercharger rating, the horsepower input of the supercharger is constant and the supercharger compression-ratio, or carbureter drop, is not of interest, since in this range the throttle is manipulated so that constant manifold-pressure is maintained.

DETERMINING CORRECTED INDICATED HORSEPOWER

The normal sea-level indicated horsepower of the engine is computed by dividing 100, the sea-level rating assumed, by the mechanical efficiency of the engine. This value is first corrected for manifold pressure. The correction for manifold temperature is next made. The difference in power output due to the difference between the induction pressure and the back pressure is next computed, after which the increase in power due to the increased charge is calculated. These values are added to the indicated horsepower corrected for temperature and pressure, and the power required to drive the supercharger is deducted. This gives a corrected indicated-horsepower from which the friction horsepower taken from the curves in Fig. 2 is deducted to give the net brake-horsepower.

These calculations were carried through, for the three

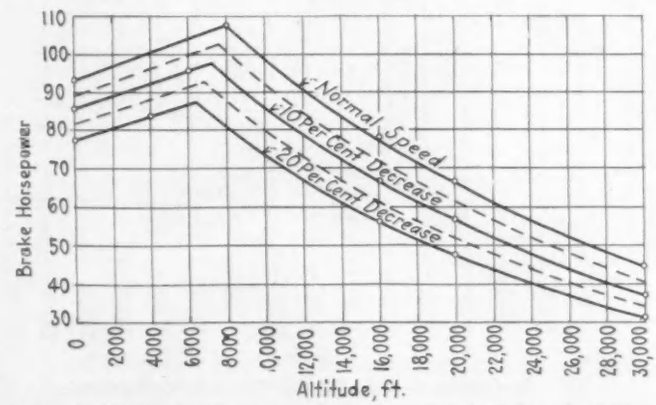

FIG. 6—EFFECT OF CHANGE OF SPEED UPON ENGINE PERFORMANCE WITH 12,500-FT. SUPERCHARGER AND NO INTERCOOLER

These Curves and Those of Fig. 5 Make Possible a Determination of the Power Available at Several Crankshaft Speeds and Any Altitude Desired

supercharger ratings selected, at normal crankshaft-speed. The results are shown in Fig. 3. For the purpose of comparison, curves are also given indicating the variation of density with altitude, Bureau of Standards results of altitude-chamber tests of the Curtiss D-12 engine, and a curve representing the average of seven Bureau of Standards altitude-chamber tests of representative aircraft-engines. Numerous calculations have resulted in straight lines up to the rated altitude of the supercharger. Only two points, therefore, were computed for this range. The numerical values for each point computed will be found in the first three groups of figures in Table 1. The curves in Fig. 4 have been prepared to show the magnitude and variation with altitude

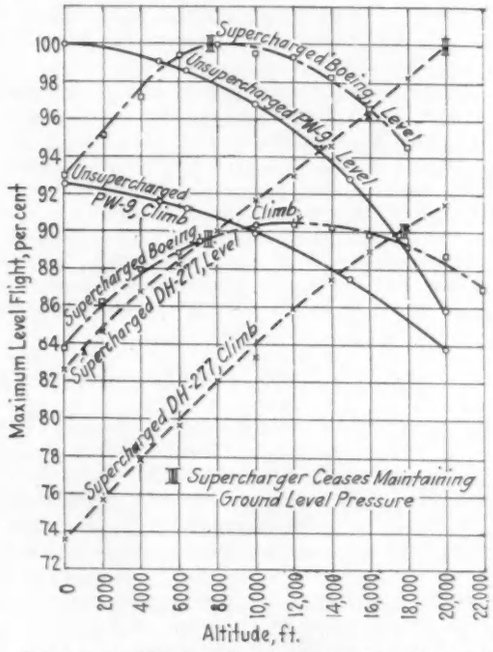

FIG. 7—CHANGE OF ENGINE SPEED WITH ALTITUDE FOR SUPERCHARGED AND UNSUPERCHARGED AIRPLANES

These Curves Were Taken from Actual Test-Flights of the Boeing PW-9 Airplane Equipped with a 7500-Ft. Geared Supercharger without Intercooler, and a DH-4 Airplane Equipped with a 20,000-Ft. Geared Supercharger with Intercooler

of each of the correction factors. The values shown are taken from the second group of figures, which gives the figures for the 12,500-ft. supercharger at normal speed. The pressure correction has a constant positive value up to the altitude corresponding to the supercharger rating and then drops quickly to negative values as the altitude is increased.

POWER OUTPUT COMPUTED AT REDUCED ENGINE-SPEED

If an adjustable propeller that would allow the maintaining of constant crankshaft-speed at all altitudes were available, the curves in Fig. 3 would be representative of the power actually available from the supercharged engine. Since, however, the fixed propeller does not allow operation at constant speed, calculations have been made for the 12,500-ft. and the 8000-ft. superchargers for crankshaft speeds below normal. As the 16,000-ft. supercharger is considered impractical because of high temperature-rise, it was not included in these calculations. In computing the power output at reduced speed, the same general method of calculation was followed, except that it was necessary to compute new values for the temperature rise, the horsepower input, and the pressure ratio of the supercharger, since all these depend upon

the crankshaft speed. Results of these calculations are shown by Figs. 5 and 6. These curves make possible a determination of the power available at any crankshaft speed and altitude desired. The numerical values for reduced speeds will be found in the last four groups of figures in Table 1.

To determine from these curves the actual horsepower available from the supercharged engine as operated in the airplane, it is necessary to calculate the propeller speed for each altitude. Such calculation involves accurate data on the variation of the propeller-torque coefficient with V/ND, which represents the velocity of airplane flight divided by the revolutions of the propeller per minute times the propeller diameter, on the variation of the propeller-torque coefficient with the density or scale effect, and on the lift and drag coefficients of the airplane and their variation with the density, or scale effect. Information is also required as to the influence of mutual interference between the airplane and the propeller and the way in which this influence varies with changes in V/ND, in airplane altitude and in air density.

This calculation is beyond the scope of this report, but,

TABLE 1—DATA ON VARIOUS SUPERCHARGERS

8000-*Ft. Supercharger; 100-Per Cent Speed; Actual Temperature Rise,* 78.5 *Deg. Fahr.*

Altitude, 1000's Ft.	Atmospheric Pressure, In. Mercury	Atmospheric Temperature, Deg. Fahr., Absolute	Carbureter Drop, In. Mercury	Supercharger Inlet-Pressure, In. Mercury	Compression Ratio	Manifold Pressure, In. Mercury	Manifold Temperature, Deg. Fahr. Absolute	Indicated-Horsepower Correction for Pressure	Indicated-Horsepower Correction for Temperature	Back-Pressure Correction	Increased-Charge Correction	Supercharger Horsepower	Net Indicated Horsepower	Friction Horsepower	Brake Horsepower
0	29.92	519.0	....	....	.....	29.9	596.5	119.0	111.2	0	0	5.3	105.9	12.7	93.2
8	22.20	491.2	1.50	20.7	1.445	29.9	569.7	119.0	113.6	3.5	6.9	5.3	118.7	11.4	107.3
16	16.10	469.0	1.15	14.9	1.461	21.8	547.5	86.6	84.4	2.6	5.1	4.0	88.1	10.3	77.8
20	13.60	460.0	1.00	12.6	1.477	18.6	538.5	73.9	72.6	2.3	4.5	3.4	76.0	9.9	66.1
30	9.40	444.0	0.70	8.7	1.495	13.0	522.5	51.7	51.4	1.6	3.4	2.5	53.9	9.4	44.5

12,500-*Ft. Supercharger; 100-Per Cent Speed; Actual Temperature Rise,* 121.5 *Deg. Fahr.*

0	29.92	519.0	....	....	.....	29.9	640.5	119.0	107.4	0	0	8.2	99.2	12.7	86.5
12.5	18.60	478.1	1.50	17.1	1.750	29.9	599.6	119.0	110.8	5.1	9.4	8.2	117.1	10.7	106.4
16	16.10	469.0	1.30	14.8	1.767	26.1	590.5	103.8	97.3	4.5	8.6	7.2	103.2	10.3	92.9
20	13.60	460.0	1.15	12.4	1.785	22.1	581.5	87.9	83.0	3.8	7.5	6.2	88.1	9.9	78.2
30	9.40	444.0	0.80	8.6	1.824	15.7	565.5	62.4	59.8	2.8	5.6	4.4	63.8	9.4	54.4

16,000-*Ft. Supercharger; 100-Per Cent Speed; Actual Temperature Rise,* 155.8 *Deg. Fahr.*

0	29.92	519.0	....	....	.....	29.9	674.8	119.0	104.4	0	0	10.6	93.8	12.7	81.1
16	16.10	469.0	1.5	14.6	2.050	29.9	624.8	119.0	108.5	6.2	11.7	10.6	115.8	10.3	105.5
20	13.60	460.0	1.3	12.3	2.075	25.5	615.8	101.5	93.2	5.4	10.1	9.1	99.6	9.9	89.7
25	11.20	450.8	1.1	10.1	2.104	21.3	606.6	84.8	77.6	4.5	8.6	7.6	83.1	9.5	73.6
30	9.40	444.0	0.9	8.5	2.120	18.0	599.8	71.6	66.7	3.8	7.5	6.5	71.5	9.4	62.1

8000-*Ft. Supercharger; 90-Per Cent Speed; Actual Temperature Rise,* 63.6 *Deg. Fahr.*

0	29.92	519.0	....	....	.....	29.9	582.6	107.0	100.9	0	0	3.9	97.0	11.4	85.6
6	24.00	498.0	....	....	.....	29.9	562.0	107.0	102.7	2.4	4.7	3.9	105.9	10.6	95.3
16	16.10	469.0	0.90	15.20	1.362	20.7	533.0	74.2	73.1	1.9	3.8	2.9	75.9	9.4	66.5
20	13.60	460.0	0.80	12.80	1.375	17.7	524.0	63.4	63.0	1.7	3.4	2.5	65.6	9.0	56.6
30	9.40	444.0	0.60	8.80	1.385	12.2	508.0	43.7	44.1	1.1	2.3	1.8	45.7	8.7	37.0

8000-*Ft. Supercharger; 80-Per Cent Speed; Actual Temperature Rise,* 50.3 *Deg. Fahr.*

0	29.92	519.0	....	....	.....	29.9	569.0	95.2	91.0	0	0	2.7	88.3	10.9	77.4
4	25.90	504.2	....	....	.....	29.9	554.0	95.2	92.2	1.5	2.8	2.7	93.8	10.3	83.5
16	16.10	469.0	0.70	15.40	1.278	19.7	519.0	62.7	62.7	1.4	2.6	2.0	64.7	8.7	56.0
20	13.60	460.0	0.60	13.00	1.288	16.8	510.0	53.4	54.0	1.1	2.3	1.7	55.7	8.4	47.3
30	9.40	444.0	0.40	9.00	1.298	11.7	494.0	37.3	37.4	0.8	1.8	1.2	38.8	7.8	31.0

12,500-*Ft. Supercharger; 90-Per Cent Speed; Actual Temperature Rise,* 98.4 *Deg. Fahr.*

0	29.92	519.0	....	....	.....	29.9	617.4	107.0	98.2	0	0	6.0	92.2	11.4	80.8
8	22.20	491.2	....	....	.....	29.9	583.6	107.0	100.5	3.2	6.0	6.0	103.7	10.3	93.4
16	16.10	469.0	1.10	15.0	1.601	24.0	567.4	85.9	82.3	3.2	6.3	5.3	86.5	9.4	77.1
20	13.60	460.0	0.90	19.7	1.608	20.4	558.4	73.0	70.5	2.7	5.4	4.5	74.1	9.0	65.1
30	9.40	444.0	0.70	8.7	1.638	14.3	542.4	51.2	50.0	2.0	4.0	3.2	52.8	8.7	44.1

12,500-*Ft. Supercharger; 80-Per Cent Speed; Actual Temperature Rise,* 77.7 *Deg. Fahr.*

0	29.92	519.0	....	....	.....	29.9	596.7	95.2	89.0	0	0	4.2	84.8	10.9	73.9
8	22.20	491.2	....	....	.....	29.9	568.9	95.2	91.0	2.8	5.4	4.2	95.0	9.7	85.3
16	16.10	469.0	0.80	15.3	1.450	22.2	546.7	70.7	69.0	2.3	4.4	3.7	72.0	8.7	63.3
20	13.60	460.0	0.70	12.9	1.463	18.9	537.7	60.2	59.3	1.9	3.8	3.2	61.8	8.4	53.4
30	9.40	444.0	0.50	8.9	1.485	13.2	521.7	42.1	41.1	1.4	2.8	2.3	4.0	7.8	35.2

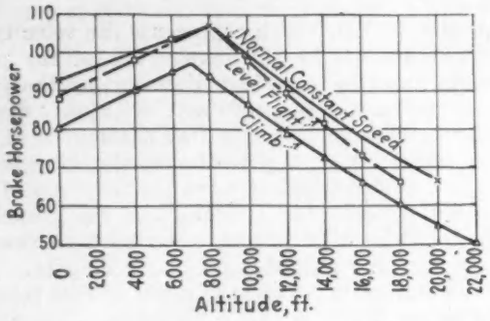

FIG. 8—EFFECT OF PROPELLER SPEED UPON ENGINE PERFORMANCE WITH 8000-FT. SUPERCHARGER AND NO INTERCOOLER

These Curves Give a Rough Idea of the Power Actually Available as Determined by Applying the Speed Curve Obtained from Flight Tests of the PW-9 Airplane Equipped with the 7500-Ft. Supercharger to the Power-Available Curves Calculated for an 8000-Ft. Supercharger-Rating

to visualize the effect of propeller speed on the power available, the curves in Fig. 7 have been included. These curves are from actual flight-tests of the Boeing PW-9 airplane equipped with a 7500-ft. supercharger without air-cooler, and a DH-4 equipped with a 20,000-ft. supercharger with air-cooler. It will be noted that the propeller speed increases up to an altitude that is approximately the rated altitude of the supercharger, and then falls off as the altitude is increased further. A rough idea of the power actually available may be determined by applying the speed curves obtained from flight tests of the PW-9 airplane equipped with the 7500-ft. supercharger to the power-available curves calculated for an 8000-ft. supercharger-rating. The results are shown in Fig. 8. These curves make no pretense of accuracy but are interesting as showing the general effect of propeller characteristics on the power available, the general tendency being to accentuate the loss in power at altitudes both below and above the normal rating.

To investigate the effect of supercharger efficiency on the total power available, the calculation was made with assumed efficiencies of 60, 70 and 75 per cent. The results of these calculations are shown in Fig. 9. It should be noted that these curves are not strictly comparable with those in Fig. 3, as a slightly simplified method of calculation was employed. The general effect, however, of supercharger efficiency is well illustrated, and this curve indicates that no serious error in the general results is to be expected from a slight error in the supercharger efficiency assumed.

ALTITUDE-CHAMBER TEST

A Curtiss D-12 engine, with supercharger attached, was prepared for testing in the altitude chamber of the Bureau of Standards. The general arrangement is shown

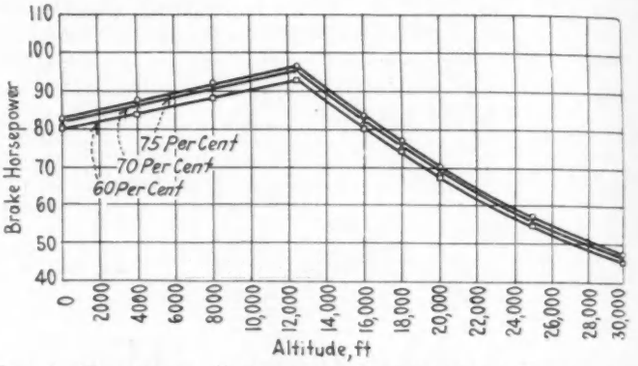

FIG. 9—EFFECT OF CHANGE IN SUPERCHARGER EFFICIENCY UPON ENGINE PERFORMANCE WITH 12,500-FT. SUPERCHARGER AND NO INTERCOOLER

Efficiencies of 60, 70 and 75 Per Cent Were Assumed. The Curve Indicates That No Serious Error in the General Result Is To Be Expected from a Slight Error in the Supercharger Efficiency Assumed

in Fig. 10, although this is not the identical equipment used in the test. The engine was standard except that the carbureters and manifolds were removed and two 3-in.-gallery manifolds were substituted.

The supercharger was of the direct-driven centrifugal

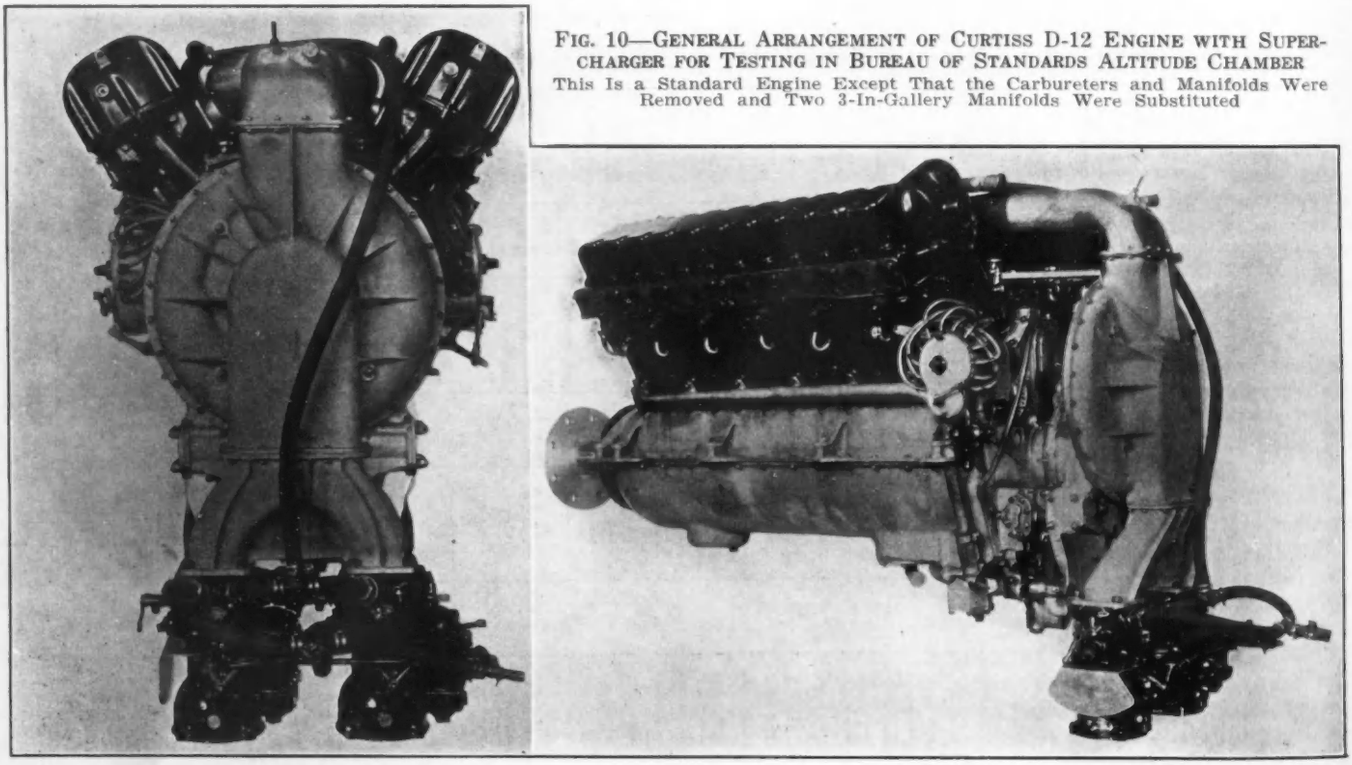

FIG. 10—GENERAL ARRANGEMENT OF CURTISS D-12 ENGINE WITH SUPERCHARGER FOR TESTING IN BUREAU OF STANDARDS ALTITUDE CHAMBER

This Is a Standard Engine Except That the Carbureters and Manifolds Were Removed and Two 3-In-Gallery Manifolds Were Substituted

type having an impeller speed 10.6 times the crankshaft speed. The supercharger casing and impeller were made by the General Electric Co., and the gear train and housing by the Allison Engineering Co. The fuel-air mixture was delivered by two Stromberg NA-S8J carbureters attached to the intake side of the supercharger.

The engine and supercharger were placed in the altitude chamber and runs were made at 2000 and 2200 r.p.m., sea-level pressure at the supercharger outlet being maintained to as great an altitude as possible. This was accomplished by opening the carbureter throttles as the altitude was increased, until the throttles were wide open. This corresponds to the peak of the power curves shown in Figs. 5 and 6.

For comparison, the sea-level unsupercharged horsepower of the engine used in the test was multiplied by the percentage of horsepower shown in Fig. 5, and was plotted with the actual horsepower as shown in Fig. 11. The power outputs are in fair agreement, particularly after the carbureter throttles have been opened. It will be noted that the supercharger used on the test actually maintained sea-level pressure at the supercharger outlet somewhat above the calculated critical altitude.

The altitude-chamber test has not been completed and runs will be made at altitudes greater than 15,000 ft.

Conclusions

This study indicates clearly that, for all-round performance to a definite altitude, an intermediate supercharger-rating should be selected; also that the performance of engines equipped with direct-driven centrifugal superchargers can be predicted with a fair degree of accuracy by the methods outlined in this paper.

In closing, I wish to thank Major Leslie MacDill, chief of the experimental section, materiel division, and Capt. T. E. Tillinghast, chief of the powerplant branch, for permission to use the information contained herein.

APPENDIX

Method of Computation

To compute the temperature rise and the horsepower input for any given supercharger rating and efficiency, we made use of the following relations:

$$\text{HP} = \frac{3.44\,W\,RT_1}{33{,}000}\left[\left(\frac{P_2}{P_1}\right)^{0.291} - 1\right] \div \text{Efficiency} \qquad (1)$$

$$\text{Adiabatic Temperature Rise} = \triangle T_a = \left[\left(\frac{P_2}{P_1}\right)^{0.291} - 1\right] T_1 \qquad (2)$$

$$\text{Actual Temperature Rise} = \triangle T = \frac{\triangle T_a}{\text{Efficiency}} \qquad (3)$$

In computing the horsepower input and the compression ratio for a given supercharger at other than rated conditions, we made use of the fact that, over the range during which the efficiency may be considered constant, the temperature rise depends only on the speed and varies as the square of this quantity.

$$\triangle T_2 = \frac{\triangle T_1 \times N_2^2}{N_1^2} \qquad (4)$$

To compute the corresponding pressure-ratio, the adiabatic temperature-rise is used.

$$\triangle T_a = \triangle T \times \text{Efficiency} \qquad (5)$$

$$\frac{P_2}{P_1} = \left(\frac{T_1 + \triangle T_a}{T_1}\right)^{3.44} \qquad (6)$$

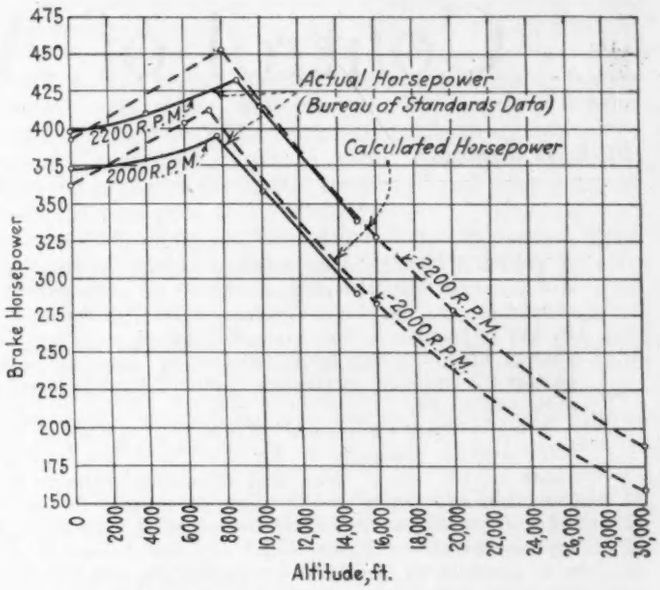

FIG. 11—COMPARISON OF CALCULATED AND ACTUAL BRAKE-HORSEPOWER OF SUPERCHARGED CURTISS D-12 ENGINE

The Power Outputs, Particularly after the Carbureter Throttles Have Been Opened, Are in Fair Agreement

The supercharger horsepower-input under the new conditions is obtained by correcting the input under the rated conditions.

$$HP_2 = \frac{HP_1 \times N_2^3}{N_1^3} \times \frac{d_2}{d_1} \qquad (7)$$

d being the density of the air entering the supercharger.

The normal sea-level indicated-horsepower is obtained by dividing the normal brake-horsepower (100 hp.) by the mechanical efficiency, 88.7.

This value is corrected for the inlet-manifold pressure by multiplying by the supercharged inlet-manifold pressure and dividing by the normal unsupercharged inlet-manifold pressure (28.4 in. of mercury), assuming a carbureter drop of 1.5 in. of mercury.

The temperature correction is then made by multiplying the indicated horsepower, as corrected for pressure by the square root of the ratio of the standard sea-level absolute-temperature (519 deg. fahr.) to the intake-manifold temperature.

The increase in power due to the reduced back-pressure is computed from the following relation:

$$HP \text{ correction} = \frac{(P_1 - P_E) \times P.D. \times N}{792{,}000} \qquad (8)$$

P_1 = inlet-manifold pressure
P_E = exhaust-manifold pressure

The correction for increased charge takes the form of a multiplying factor that is applied to the indicated horsepower, corrected for pressure and temperature. This factor is obtained from the following:

$$F = \frac{1}{R-1} \times \frac{P_1 - P_E}{P_1} \qquad (9)$$

in which R = the compression ratio, and P_E and P_1 are as given above.

Control of Aircraft Design

By E. W. STEDMAN[1]

AERONAUTIC MEETING PAPER

DIFFICULTIES experienced in regard to the engineering features of the control of civil aviation during a period of 7 yr. are summarized by the author in the expectation that they will afford a better exchange of ideas and be productive of data and suggestions from other engineers that will tend to obviate such difficulties.

After giving an outline of the formation of the International Commission for Air Navigation subsequent to the Great War and commenting upon the Canadian Air Board Act of 1919, the author discusses the I. C. A. N. minimum requirements of aircraft and engines for airworthiness which are now being worked to in Canada as closely as possible. He criticizes the apparent unfortunate tendency of aircraft designers purposely to pare their design down to the lowest figures that will meet the minimum requirement, and suggests improvements in design practice in this respect.

The extreme difficulty attendant upon the inspection of aircraft and the certification of used aircraft as to airworthiness is emphasized. The suggestion is then made that regulations must make the minimum requirements for strength and performance sufficiently great to allow for reasonable deterioration of structure and the loss of engine power; but, in the author's belief, the correct remedy undoubtedly is for the designer to accept the principle that he must design his aircraft so that, with reasonable maintenance and life, the strength and performance will never fall below the minimum as laid down or that they will be greater if the designer is of the opinion that the minimum is too low.

The effect of increasing load-factors is discussed as well as the subject of what load factors are desirable, and their proper grading. The author concludes by making an appeal to other engineers for data and suggestions concerning the determination of what recommendations should be made for strength and for performance requirements.

FOLLOWING the Great War, a number of European countries entered into an agreement upon the conditions under which international flying should be carried out. One of the most important parts of this agreement required each contracting State to certify the airworthiness of its own aircraft, when these aircraft were used for international flying. Canada became a contracting State under the International Commission for Air Navigation, abbreviated hereinafter as I. C. A. N., and the Canadian Air Board Act of 1919 created an Air Board with powers for "supervising all matters connected with aeronautics, and preparing such regulations as may be considered necessary for the control and operation of aeronautics in Canada and within the limits of the territorial waters of Canada."

The 1920 Air Regulations were approved by the Governor-in-Council on Dec. 31, 1919, and provided the necessary details for administering the Air Board Act. The National Defence Act of 1922 transferred the powers, duties and functions vested in the Air Board to the Department of National Defence.

MINIMUM STRENGTH OF AIRCRAFT

In order that a country could certify the airworthiness of its aircraft, and that other countries would be willing to accept this certification, it obviously was necessary to have some standard of strength requirements that was acceptable to all countries concerned, and this resulted in the issuance by the I. C. A. N. of a statement of minimum requirements of strength and performance of aircraft and engines for airworthiness. These minimum requirements of the I. C. A. N., which have been widely circulated and can be obtained by any designer who is interested, are now being worked to in Canada as closely as possible.

Apparently there has been one bad result from the adoption by various governments of a definite set of minimum requirements; that is, there has been an unfortunate tendency for aircraft designers purposely to pare their designs down to the figures necessitated by these minimum requirements. I am well aware of the arguments on the designers' side in favor of doing this and, in fact, when employed as a designer by a well-known British aircraft manufacturer, I followed exactly the same practice. It is somewhat difficult to understand precisely how this tendency has arisen; because, although an aircraft may be sufficiently strong when first constructed to these minimum requirements, it is certain that these requirements are not fulfilled after the aircraft has been in use for even one season. All engineers probably will admit that however good the maintenance of an aircraft or engine may be, its condition cannot be maintained at 100 per cent perfection. It seems reasonable that the designer should give more consideration to the fact that the failure of any part of an aircraft, even though certified as airworthy by a government department, does great harm to his business, and that he should design to allow an ample margin to meet all service conditions rather than to design so that his aircraft will just scrape through on the minimum requirements allowed by existing regulations.

It is noted that the Air Commerce Regulations list the minimum load-factors and add a qualifying phrase "as when new," which leads one to believe that the listing is intended to cover reasonable deterioration in these figures. It would be interesting to know if this is true and, if so, how one can determine the amount of deterioration that can be allowed and still retain airworthiness.

INSPECTION OF AIRCRAFT

Any engineer who has been required to inspect an aircraft that is several years old and that has, in addition, been overhauled by a number of different persons, will appreciate the difficulty that one experiences to certify

[1] Wing commander, Royal Canadian Air Force and chief aeronautical engineer, Department of National Defence, Ottawa, Canada.

conscientiously the airworthiness of the aircraft in its present state, particularly when it is known that the type of aircraft originally was designed exactly to the minimum load-factors, even to the nearest decimal point. There is no duty in the licensing of aircraft that is more unsatisfactory than the certification of used aircraft. An example will indicate the difficulties experienced, in making satisfactory certification.

A flying boat recently disintegrated in the air and, upon investigation, it was thought that failure occurred following a dive through clouds at high speed because the aircraft was pulled out of the dive too quickly. The failure that occurred was that the nose of the boat broke off downward. For determining whether this failure occurred at an abnormally low load-factor, a sand test was made of a nose portion of a similar hull, constructed at about the same time as was the aircraft that crashed. This sand test indicated that the failure of the hull must have occurred at a load which was on the point of causing failure of the wing structure, and at a load about equal to the minimum requirements in force at the time this type aircraft was constructed; but an interesting point is that failure of the hull, which apparently was in good condition and serviceable and which undoubtedly would have been passed as airworthy by any engineer, occurred at about one-half the strength of the hull as calculated when the type was examined for structural strength. The reduction in strength was due to the deterioration of members, under fittings, that could not be detected by any visual examination. This factor of deterioration due to service cannot be over-emphasized because it is entirely neglected by the present minimum requirements.

What Is the Remedy?

The apparent answer to these queries is that the minimum requirements for strength and performance as fixed by regulations must be sufficiently great to allow for reasonable deterioration of structure and the loss of engine power, but this does not actually seem to be the correct answer. If the requirements are increased, they no longer become minimum requirements because we know that they will not be maintained in service and that, in service, we actually will be content with less. The correct answer undoubtedly is for the designer to accept the principle that he must design his aircraft so that, with reasonable maintenance and life, the strength and performance will never fall below the minimum as laid down, or that they will be greater if he is of the opinion that the minimum is too low.

Effect of Increasing Load-Factors

We may inquire whether a small increase in load factors actually means very much in performance. From examinations of many different types of aircraft for checking the design and determining the load factors, experience seems to indicate that very slight increases in the size of the members would bring them well above the minimum requirements, and the additional weight required for this purpose actually has been put into the aircraft by non-essential accessories in almost every case.

At present, such great advances are being made in the design of commercial aircraft that it is felt that some advance can well be expected toward greater strength of aircraft. Undoubtedly, in the ultimate case, commercial aircraft must fall in line with other engineering structures and be designed to meet any condition that may arise during their life with a reasonable factor of safety to cover material faults, errors of workmanship, and deterioration. It has been argued that, in aircraft, a much better control of material and workmanship is maintained than in general engineering practice, due to better inspection facilities. This, however, appears to be a poor argument, because field repairs generally are made without specialized inspection, in many cases from material obtained locally, and usually by a mechanic who must of necessity be a jack of all trades.

It appears to be very undersirable to lay down a fixed requirement for the actual load-factors to which an aircraft should be designed, but each designer should consider for himself to what figures he should work so as to suit the particular condition under which his aircraft will be used, and to make sure that he has sufficient reserve of strength to protect the good name of his company should an unfortunate, but not necessarily unpreventable, accident occur. The load factors so chosen should be so high that there never would be any question of a decimal place in the load factor when the design is checked officially to see that the minimum requirements had been met. The methods that must necessarily be adopted in calculating the strength of aircraft involve so many assumptions that no engineer would think of maintaining that his calculated load-factors were accurate to the last decimal point. In checking the calculations, if a slightly different assumption is made, there should be no question about whether the parts of the aircraft come up to minimum requirements.

By voluntarily working along these lines, using load factors well above the minimum requirements but keeping a much closer check on the weights of non-essential parts, which add nothing to the strength but detract from the strength by reason of the weight added, the designer can be more sure of retaining the good-will of his customers.

Many people naturally will ask what actual figures are recommended. This at once opens up one of the most persistent arguments in the science of aeronautical engineering. The answer depends largely on circumstances; but, for ordinary commercial purposes involving all-weather flying such as on an air-mail service, it is believed that the designer today certainly should design to load factors not lower than those called for under the acrobatic class of the I. C. A. N.; namely, for the center of pressure in its most forward position the load factor varies uniformly from 9 for an aircraft of 1000-kg. (2205-lb.) total weight to 7 for an aircraft of 5000-kg. (11,025-lb.) total weight. However, it should be made clear that the minimum requirements for load factors, as laid down by the regulations, should not be raised above the present figures; namely, varying from 7 to 5 according to weight. The designer would then have a sufficient margin to make certain that, when the design was checked officially and perhaps a slightly different assumption taken in the calculations, the load factors of his aircraft parts would not be likely to be found below the minimum requirements.

The load factors recommended in the foregoing paragraph are by no means to be pointed to as the ultimate figures, because commercial aircraft of the future must be incapable of being broken in the air; therefore, as the art advances we should review our practice continually to see that it is keeping pace with the times. It is not intended to convey the impression that avoiding the possibility of failure in the air ultimately must be obtained by the use of great structural strength if other improvements in the art will achieve the same results. The answer remains the same, however, and it is desired

to emphasize this point particularly so that, by the time commercial aviation becomes universal, aircraft shall be incapable of being broken in the air.

Grading of Load Factors

The much discussed question of the grading of load factors to suit types and sizes of aircraft now arises. The variation of a load factor according to total weight of the aircraft without any reference to power loading seems very unsatisfactory, but here again the designer of a high-performance aircraft should not use a low load-factor just because he is permitted to do so by the regulations.

Information Desired by the Author

Many features in aircraft design are not yet covered by the I. C. A. N. requirements. Regulations covering these must soon be introduced for the sake of uniformity, and I shall welcome suggestions bearing upon the following questions in which the experience of other engineers would assist greatly in determining what recommendations should be made upon these points.

(1) What should be the strength requirements for commercial passenger-carrying flying-boat hulls, to cover both local failure due to blows and the strength of the cross-section at the cockpits?
(2) What should be the strength requirements for seaplane floats under similar conditions?
(3) What should be the performance requirements of a commercial seaplane or a flying boat?

The advisability of licensing an aircraft by a government department often has been questioned, and the opinion of other engineers will be welcomed upon whether it is possible to hope that, in the future, the licensing of aircraft can be covered by a simple enactment requiring that all aircraft and personnel engaged in civil aviation, including passengers carried, must be covered by insurance. If such a scheme were properly organized it is thought that licensing by a government department could be dispensed with, and that many of the problems would disappear due to the fact that the acceptance of the risk for aircraft and passengers by an insurance company is a business transaction, automatically involving the checking of the strength of aircraft and the periodic inspection of the aircraft during service.

Farmers Buying More Cars

"RURAL registration of automobiles is increasing in the United States," says J. W. Frazer, sales manager of the Chrysler Sales Corporation. "The more our farmers have of all kinds of gas power, electric power and mechanical equipment the sooner they will leave behind them the troubles that have been making their lot so difficult."

The Chrysler official's comments were prompted by a farm paper's discussion of the views of a statistician who called on its editor and blamed automobiles for farm problems of the Country.

The statistician argued like this:

Automobiles and trucks, with some help from tractors, have decreased our horse population by 8,000,000 since 1900. This has shifted 24,000,000 acres, which were formerly used to feed work stock, over to the production of human food. If only 15,000,000 of these acres are tillable land, that means, in terms of corn, 450,000,000 bu., which is more than our 1926 corn surplus, an excess that has been representing a goodly share of the farm problem.

The statistician might have added that probably we would have no surplus crops but for tractor-plows and gas-driven combines, continued Mr. Frazer. But the editor raised the pertinent question whether the farmer today would be willing to exchange his car for a horse and buggy. Would any farmer step out from under his financial worries and other cares if he could, by trading his speedy access to town, his riding and power machinery, his radio and the like, for dad's working tools and isolation?

The farmers must have more mechanical help if they are to hold their end with the cities, where machinery steadily increases the worker's productive power, thereby giving him a large measure of good things for fewer working hours. If farmers are to share in this progress, they must adopt the same methods; they must similarly multiply their own productive power into larger and larger outputs.

Farmers know this. They know that the old simple ways will no longer serve. In the days of these there were few things for farmers to buy, few men producing anything except soil stuffs.

But now for every farmer there are at least three men engaged in other activities. Wherefore, every farmer must now feed and clothe three men in the industries, if he would have them all work for him, if he would have something of what they all produce; if, in other words, he would enjoy an American standard of living.

That is the farm problem. The required increase of individual farm production has enlarged the aggregate output, temporarily depressing prices of some items and thus squeezing a few farmers off the land.

But all farmers are better off, both those who continue farming and those who have been forced into other work, than they would be if all had remained on the land, dividing the total farm income among more homes, and each accordingly having less money to spend for city goods.

It is a significant fact that last year there was a 5-per cent gain in rural registration of motor-cars. It is also interesting to note that, in terms of staple farm products, it costs the farmer 11 per cent less to pay for his automobile or truck today than it did in 1913; in other words, the exchange value of wheat, hogs, wool, cotton, corn and cattle for motor-vehicles is from 1.10 to 2 times greater today than in 1913.—*Motor Travel*

Technical Problems of the Control of Airplane Airworthiness

By CLARENCE M. YOUNG[1]

AERONAUTIC MEETING PAPER

Activities of the Department of Commerce concerned with the regulation of commercial aviation are dealt with in the following paper. Many questions that are difficult of solution are arising with relation to structure, materials, powerplants, equipment, pilots, operation and maintenance. These are discussed.

The Department of Commerce has no desire to become paternalistic, to limit or inhibit design or to inspect all materials of construction.

Authority is now divided between the Federal Government and the several States, but it is expected that this situation will be remedied at the next sessions of the legislatures.

Of two Federal appropriations aggregating $4,000,000, *more than three-quarters was for the establishment and maintenance of airways. Only about* $350,000 *was made available for enforcement of regulatory provisions.*

Since February, 1927, *a total of* 8000 *applications for licenses for airplanes, pilots and mechanics has been received.*

UNDER the Air Commerce Act of 1926 the Secretary of Commerce is charged, to put it in a general way, with the encouragement and regulation of the use of aircraft in commerce, immediate control being vested in an assistant secretary for aeronautics appointed by the President. This paper will be devoted only to the phase of the activities of the Department of Commerce that are concerned with the problems of regulating commercial aviation.

The promulgation of suitable regulations was the initial problem. Those which we now have are the result of much initial effort in preliminary preparation, and represent the viewpoint of representatives from every branch of the aviation industry, obtained not merely by correspondence but by a series of conferences held prior to their adoption. They will need amendment from time to time; in fact, they need it now, and another conference has been scheduled for the week of Dec. 4, to which the industry has been invited, for the purpose of considering the proposals. The policy of the department in this respect is one of cooperation rather than domination, and the viewpoint of the manufacturers and operators will always be sought.

Development of rules and regulations to assure the airworthiness of all sorts of aircraft is involved in the Air Commerce Act, but since the airplane is the predominant form of flying-machine at present, the activities of the department are focused upon that type. Balloons; non-rigid, semi-rigid and rigid airships; helicopters; ornithopters and such other forms of aerial transport as may yet be developed must be taken care of as their employment in commercial enterprises becomes imminent.

The very definite increase in the demand for airplanes and the rapid growth of the airplane-manufacturing industry in the last few months has kept the department's organization busy and given it little opportunity to develop regulations looking toward the control of the more unusual types of aircraft. It is anticipated that the winter and early spring months will bring a reduction in the rather intense activities and give the department an opportunity to devote time to the solution of some of the more important problems it can now foresee. The indications are, however, that some manufacturers will carry on through the winter months with a view toward accumulating stocks to meet the demand for early-spring deliveries. Such being the case, the department must continue to give its attention almost entirely to improving the airworthiness of commercial-type airplanes, a problem which has so many ramifications as to preclude, apparently a complete and satisfactory solution for some time to come.

THREE CATEGORIES OF AIRWORTHINESS

The airworthiness of the airplane may be divided into three relatively independent categories: (*a*) strength and arrangement of the structure; (*b*) reliability of the powerplant, appurtenances, and equipment; and (*c*) competence of the operating personnel.

It is obvious that wings, fuselage and tail surfaces must have sufficient strength to withstand the loads to which they will be subjected in flight and must be so disposed in relation to one another that the resulting airplane will be relatively stable and safe to fly. At the same time, the engine, propeller and equipment must be sufficiently dependable to assure that failures will be uncommon and forced landings reduced to the minimum.

The technical problems involved in regulating the airworthiness of the inanimate airplane as a whole may, therefore, be segregated into five groups, each of which is, apparently, of equal importance with the others. As grouped, they relate to engines and propellers, instruments, structural design, materials, and maintenance.

COMMERCIAL ENGINES WILL NEED TESTING

At present the production of airplanes is built up largely around engines designed for the Army or Navy, tested by them and, in many cases, developed by several years of service. Since both military and commercial usages require maximum power and reliability with minimum weight, the availability of three or four good military engines has been a great boon to the commercial manufacturers during their recent rapid expansion. It has, moreover, relieved the Department of Commerce from developing complete regulations for, and perform-

[1] Director of aeronautics, Department of Commerce, City of Washington.

ing tests on, new types of engine. But the day is at hand when facilities must be provided to determine the dependability of commercial engines. It is probable that the department, acting through one of its divisions, the Bureau of Standards, will take over the testing and regulating of commercial-airplane engines and will endeavor to develop specifications to improve the reliability of the airplane powerplant as a whole.

While this seems to offer an extremely satisfactory solution for this problem, it entails certain questions as yet unanswered. An important one is, Who is to bear the cost of the tests? Since the department will require tests and as the tests will, of necessity, involve an expenditure of from $500 to $1,000 each, should the department, under the guise of encouraging aviation, stand this expense? Manufacturers of engines in small quantities will, of course, say "Yes," and such an arrangement would have a particular appeal to certain types of "inventors" and promoters. It would enable them to submit an incomplete or unsatisfactory design and demand to know why it failed during test, thus placing the burden of the engineering upon the department to a considerable extent; also, they could practically monopolize the available equipment and personnel of the department by making slight changes and so-called improvements which would require new tests, and, besides delaying the testing of well-executed designs, they could eventually develop a satisfactory engine, largely at the Government's expense. Obviously this is not desirable. Somewhere between these two courses there should be a solution not too burdensome to the small manufacturer, yet not involving a Government subsidy, indirect though it might be. Just what the solution will be is for the future to decide. Whatever it is, it must give reasonable assurance that the approved product will be airworthy.

The problem of the airplane propeller is similar to that of the engine; that is, a large number of propellers have been designed for military engines and airplanes, and these designs, being available, have been adapted to commercial purposes with fairly satisfactory results. The development of new engines and new airplanes will require new propellers and, although the department has not yet drawn up specifications as to methods of design, construction or testing to assure dependability, it has this problem in mind and anticipates a suitable solution.

Must Evolve Procedure for New Instruments

At present our regulations cover the question of the number of instruments to be carried in an airplane but specify nothing as to what is necessary to assure the reliability of any given instrument. This has not been necessary so far, as virtually all instruments available have been built to Army or to Navy standards and the test of years of service has ensured their accuracy. But developments in this field are to be expected, and here again it doubtless will devolve upon the department to devise methods for testing and determining the dependability and airworthiness of new instruments. The exact procedure has not as yet been formulated but, since the recognition of a problem is a substantial contribution to a solution, we feel that the rest of the problem is, perhaps, a detail, especially since we have available the methods employed and the experience gained by much of this work done by the department at the Bureau of Standards for the Army and the Navy Services.

Stress Analysis on Plane Structure Required

As for the airplane itself, amended regulations covering structural design have been derived to give reasonable assurance that the resultant assembly of parts will not fail under normal flying-conditions, and the flight tests required on each airplane are sufficient to indicate to a competent pilot whether the design is safe under ordinary handling. A rigid test of each new type of airplane demonstrates its ability to take off within a reasonable distance. It shows whether the controls are effective, whether the plane is dangerously out of balance, and similar characteristics which depend upon its general aerodynamic design. Such a test is performed by the department's inspectors before a plane is licensed to make certain of safety in the air under normal conditions.

Effective Oct. 1, 1927, a stress analysis must be submitted on every type of airplane that is to be licensed. It would be of no use to require an analysis with every airplane of a type produced in quantity; therefore, to provide for this situation, an "approved-type certificate" has been arranged which permits a manufacturer to build as many craft of exact similarity to the type approved as he desires.

The requirements for the stress analysis are, to some extent, based on the result of 8 or 10 yr. of Army and Navy experience, modified to provide for the less severe loads encountered in commercial flight. This modification is made chiefly in the required load-factors. These factors have been drawn to provide sufficient strength in the structure to withstand the loads coming on an airplane in straight flight, with an allowance for abnormal weather conditions. It has been found, however, that some of the smaller more maneuverable types have such good performance and inspire so much confidence in the pilots that they are stunted and overloaded, with an occasional failure as a result. As this has occurred in some cases with the OX-5 engine, it has brought up a question as to the probable result with greater power of the same approximate weight in the same type of plane. It seems certain that the excess power would, in most cases, inspire greater confidence, that more severe maneuvers would be attempted and more failures would result.

Since accidents, no matter what the cause, are regarded by the layman as not only a reflection on a particular type of plane but upon the safety of air travel in general, and since one important phase of regulation is the elimination of known hazards, it has been decided that load factors must be increased for present minimum requirements with the object of decreasing the probability of structural failures.

New Classification by Load Factor

The present method of classifying types of airplane as to load factors depends solely on gross weight, and it is now possible to substitute a Whirlwind engine in an airplane designed around an OX-5 engine, add a few pounds to the useful load, obtain a more maneuverable airplane, and design for lower load-factors. This is obviously wrong, hence a new method of classification has been devised and will soon become effective. It differentiates the smaller two and three-place highly maneuverable planes from the more stable cabin and cargo carriers. The load factors required for these types are then graduated according to gross weight and weight per horsepower, the lighter higher-powered airplane having the higher factors.

While it is realized that the most satisfactory criterion for load factors is the speed range, that is, the ratio of maximum speed in horizontal flight to stalling speed, we have found that the manufacturers' estimated stalling or landing-speeds are not sufficiently accurate to furnish

a suitable premise for the calculations involved. A surprisingly large number of planes, if one is to believe the advertised performance-figures, have speed ranges between 3 and 4, and this in the face of the fact that the utmost refinement in pursuit and racing airplane seldom suffices to give a range of 3.5. Although the desirability of adopting a system of design load-factors that would automatically assure accuracy in representing the high and low speeds of flight is recognized, the difficulty of predicting the high speed is also realized and, since the predicted high speed would in most cases be the one on which the speed range will have to be based, consequently determining the load factors to be used with the structural design, it was concluded that the scheme of basing load factors directly on speed range was not satisfactory for the present.

Speed Range an Unsatisfactory Basis

Assume, for example, the predicted high speed to be 75 m.p.h. and the stalling speed to be 30 m.p.h., the speed range would be 2.5. Since the load varies as the square of the velocity, the required factor would be 6.25 times some more-or-less arbitrary coefficient, times the basic load. But suppose the plane, when tested, actually made 80 m.p.h., the stalling speed remaining at 30 m.p.h., the speed range would be 2.67 and the factor required in design would be 7.1, or nearly 14 per cent greater. Such an error would, in all probability, require a complete revision of the stress analysis, with consequent changes in design and loss in time and money.

Since design load-factors are largely empirical at best, based upon the behavior of different airplanes in service, it was concluded that an arbitrary system was, in all probability, more satisfactory than a semi-theoretical method based upon computed speeds that are none too accurate. The solution of this problem, which caused considerable concern, was, as stated, the more arbitrary method of classification as to gross weight and power loading. This method, when applied to several types of airplane, gave factors that seemed reasonable from the standpoint of experience, whereas the theoretically correct method based on speed range resulted in ridiculously high factors when the best available, though admittedly unreliable, speed data were used.

Butt Welds in Tension Not Allowed

Such technical problems as those involved in a change of load factors will, it is hoped, be infrequent, but many minor difficulties are to be expected. One of those most frequently encountered at present is to what extent the dictates of good practice shall be followed in structural design. Experience has shown that butt welds in tension are unreliable and should not be permitted in the main framework of an airplane. For safety's sake, the department feels justified in requiring that they be eliminated, if we find them used, before an airplane is approved and licensed. Experience has also shown that elevator hinges rust and bind if ample provision is not made for lubrication. This is a relatively minor maintenance problem rather than one involving the safety of the airplane, though the latter is obviously affected, and we do not feel justified in requiring a definite means of lubrication, desirable though it might be.

Obviously, between these two details of good practice there are many others involving questions some of which concern safety and airworthiness directly and some indirectly. Those that have an obvious effect on safety can be taken care of by requiring that unsatisfactory features be altered. Those that have an indirect effect are more difficult. The department has no desire to become paternalistic, to limit or inhibit design, and therefore is often in a quandary to know whether to suggest that some item, which it feels confident will prove annoying in operation and maintenance, be changed, or to remain silent and permit the manufacturer to learn from operating experience. Answers to such problems seem obvious at first glance, but each has a number of phases and each seems to require a different answer.

Questions of Inspecting Materials

A stress analysis and design that indicate a structure having ample strength to carry the required loads are of little value if the materials and workmanship in the airplane are not suitable. This raises one of the most serious of the problems now before the department. Most manufacturers are using materials of a quality commensurate with the requirements of the airplane, but some are content with the best that can be obtained locally, and in many instances the supply is small and the selection exceedingly limited. In one case that has come to attention, a manufacturer obtained part of his supply of spruce for wing spars from the West Coast and part of it from the nearest large city. That which came from the coast was inspected before shipment and passed as suitable for airplane use. When this wood was routed and dressed down for wing spars, a second inspection at the manufacturer's plant resulted in rejections of about 25 per cent. A similar inspection made on the local material, the best obtainable in that vicinity, resulted in rejections of about 60 per cent.

Another manufacturer's practice was to use spruce as it came to him after a similar inspection on the West Coast, the manufacturer making no inspection at his plant. Other manufacturers have used the locally available material apparently with only the most cursory inspection. The need for careful inspection is obvious and too much emphasis cannot be placed on the necessity for making the inspection after the wood is dressed down and ready to be put into the wing structure, as many defects are brought to light only after the wood has been worked.

It sometimes happens that, after purchasing agents have made estimates as to the quantities of some item required, unforeseen expansion has suddenly caught them with a small supply of some material or of some item requiring particular material and special care. The result has been a rush to find a substitute, and the substitute was not always satisfactory for the purpose. Here again, the department hesitates to become paternalistic and place an inspector in each factory to reject all such material, since it feels that a manufacturer should set his own standards and see that they are maintained. We are learning from the occasional visits of our inspectors that some of these standards are much too low and the department may, to assure safe and airworthy airplanes, be forced to set the standards and provide, in some cases, the inspectors to maintain them. This is an important problem and one for which the most obvious solution probably would be the most unsatisfactory to the industry at large. Just what will be done to guarantee the use of suitable material has not been determined, but, considering the questions of safety involved, whatever methods are finally adopted must be definitely effective.

Plans for Maintenance Inspections

The maintenance of aircraft in a continued airworthy condition presents difficulties from the department's point

of view. An airplane may be in excellent condition and airworthy today and wholly otherwise tomorrow. Obviously, it is not possible for our inspectors to maintain a daily-inspection system. Nor is there a desire to do so under existing circumstances. It would call for too much supervision and hinder operations. Rather, the regulations impose upon the owner or operator the burden of maintaining his aircraft in continuously airworthy condition. They provide for daily and periodic inspections by licensed mechanics and require suitable entry in log books which are open to scrutiny by department representatives. Also, unannounced inspections of the aircraft are made by department inspectors when opportunity affords. The future plan in this respect is to have inspection districts small enough so that the inspector in each will be enabled to know and to maintain suitable contact with all aircraft and operators within the district, to furnish more efficient service in the enforcement of air-traffic rules, to investigate accidents, to inspect aircraft, and to assist otherwise in maintaining a uniform standard in all aviation activities.

Divided Regulatory Authority Unsatisfactory

One other matter which, though not of a technical nature, is sufficiently a problem to be mentioned, is that of regulation by the State. As it is now, the Department of Commerce, being a federal agency, has control only over interstate flying so far as licensing is concerned. While it is empowered to, and does, require that all airplanes carry identification numbers whether or not they are engaged in interstate commerce, it cannot establish minimum requirements for airworthiness in airplanes operating solely within one State. As a result, airplanes that are condemned by the department's inspectors and refused licenses for interstate commercial use may obtain identification numbers and operate within their own States, carrying passengers or property.

This situation will, in all probability, be altered by legislative action in the next sessions of the various State legislatures, but until such action has been taken, effective regulation of all aircraft is impossible. And, since the layman will not consider the airplane a really safe means of transport until regulation is general and accidents are reduced in number, some action must be taken, and that as soon as possible, to eliminate the condemned or unairworthy airplane completely. It makes no difference to the man in the street whether he reads in his newspaper that the airplane which crashed yesterday, if one did, carried identification number 1000 or license number C-1000. That the identified plane might have been any old "crate" while a licensed airplane would have been inspected and passed as airworthy, probably would not be considered. It is a subject requiring earnest consideration.

Many practical problems confront the department in the matter of regulation. The solution of them often proves to be as difficult as some of those involved in the various technical phases. However, much has been accomplished in the few months of active operation and there is reason to believe that the near future will see very definite progress in bringing about a combination of four very essential elements in the successful operation of commercial air-transport; that is, airworthy aircraft piloted and maintained by competent personnel and operated over safely equipped airways in conformity with standard air-traffic rules.

Man-Production and Pay

IF we deflate the totals to a common price-basis, it appears that the actual volume of manufactures in 1925 was some 40 per cent greater than in 1919, showing that with a decreased number of workers who received higher wages, a very material increase in production has been effected in the last 7 years.

The worker in increasing his output has been aided greatly by steadily improved and increased equipment and power, and also by intensive systematization accompanied by better business management. But for his part he certainly has been and is entitled to share pecuniarily in results. Of this, Secretary of Labor Davis, in *Printers' Ink*, says in part:

> In 1850, each man engaged in the production of pig iron turned out an average of 25 tons of iron, under the old hand-work methods. In 1904, the average man production was 470 tons; in 1909, it had grown to 671 tons; in 1919, it was 811 tons, and today it amounts to 1179 tons. Of course, this rate of increase is not typical of all industries, but in practically all trades man-production has far outstripped man-pay, and the productiveness of the American factory workers is the wonder of the world. Therefore, since the demand for all factory production so largely depends on the prosperity of the individual worker, it is certainly obvious that an adequate wage should be maintained.

And this flood of wages, enormous in the aggregate, has poured into the Country's business, helping to produce the vast volume of demand that has made for prosperity.—*Bache Review.*

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Department of Commerce National Airways Engineering

By FREDERICK C. HINGSBURG[1]

AERONAUTIC MEETING PAPER *Illustrated with* DRAWINGS AND PHOTOGRAPH

AIRPLANES now fly 16,000 miles daily over National airways, carrying mail and express. Some carry passengers. Twelve air-transport companies operate this system of transportation.

Under the Air Commerce Act of 1926, the public will be assured of the use of airworthy planes flown by competent pilots in accordance with the prescribed traffic rules over safe airways.

To date, 4120 miles of National airways have been lighted for night flying, and the lighting of 3400 additional miles next year is contemplated.

In the accompanying paper the author describes the procedure of the airways division of the Department of Commerce in locating and establishing landing-fields between airports on the airways; ground markers, beacons and signal lights; boundary markers and obstruction lights; route designation signs; and other provisions made for the guidance and safety of pilots.

Radio equisignal beacons have been established at Hadley Field, New Brunswick, N. J., and Bellefonte, Pa.; and a third is contemplated at Cleveland. A small airplane radio-receiver suitable for single-pilot airplanes used by the Air Mail has been developed commercially.

The Weather Bureau has established 34 upper-air meteorological stations and furnishes weather forecasts of flying conditions to the airports. Twenty-eight airways weather-reporters were supplying data to terminal fields along the Transcontinental Airway on June 30, 1927, and this service will be extended to other routes.

Radio telephone and telegraph are used for communicating weather information, reports of arrivals and departures of airplanes, emergency messages and other information between airports.

The airways division was established in the Lighthouse Service, and work in connection with air-navigation facilities has been assigned to the lighthouse districts. The extension and construction section of the airways division now has 16 licensed air pilots and 12 engineers. Maintenance of airways is provided for by expansion of district offices of the Lighthouse Service.

THE Air Commerce Act of 1926 provides for the erection, operation and maintenance, along civil airways established by the Secretary of Commerce, of all necessary air-navigation facilities except airports; for encouraging the establishment of airports, civil airways and other air-navigation facilities; and for the examination as to their suitability and the rating of air-navigation facilities available for the use of aircraft.

Each day airplanes fly 16,000 miles over National airways on regular schedule, carrying air mail and express. Some of these airlines have started passenger service. This new system of transportation is at present controlled by 12 air-transport companies. The growth of this system of fast transportation may be attributed to the Air Commerce Act of 1926, enacted to foster and sponsor air commerce, to regulate the use of aircraft, and to provide a system of National airways. Under the law, the public will be assured of the use of airworthy planes flown by competent pilots in accordance with prescribed traffic rules over safe airways.

To date, 4120 miles of National airways have been lighted, and the lighting of 3400 additional miles is contemplated for the next year. The National airways are being laid out over the best flying country between commercial centers, and they are provided with facilities for safe flying by night or day. These facilities include intermediate landing-fields, a system of airway lighting, a comprehensive weather service, fast communications for making the weather forecasts available to pilots, and a system of radio beacons and radio-telephone communication to airplanes. The lighting system, weather service and communications are now being provided. The radio service is in the development stage and will be provided as soon as equipment for it is perfected.

SURVEY OF NATIONAL AIRWAYS

A civil airway is a course about 5 miles in width laid out between commercial centers, taking in the airports at designated Air-Mail stops, and provided with facilities for safe flying. Civil airways to be established are designated by the Secretary of Commerce. The facilities to be provided consist of intermediate landing-fields, lights for night flying, weather service, communication, and radio beacons. The airways are laid out to follow the best flying-country and having regard to the facilities to be provided, the resultant safety of flight, and a high aim for completed trips made on scheduled time.

The surveys are made by the survey section of the airways division of the Department of Commerce operating in parties of four men, all of whom are air pilots who have been granted transport licenses and who are selected for the work on account of their real estate and engineering experience. A reconnaissance survey is made by airplane to locate tracts suitable for landing-fields, mark them on maps, and take aerial photographs. Thereafter these tracts are inspected from the ground, using automobiles for transportation, and negotiations are started for the rental of desired fields. When full information is available, fields located approximately 30 miles apart along the proposed route and that combine all possible advantages are selected.

An intermediate field should have two runways, preferably not less than 1800 ft. long and 400 ft. wide, to permit landing and taking off in four directions, with

[1] Chief engineer, Airway Division, Department of Commerce, City of Washington.

surfaces that are fairly smooth, as nearly level as possible, and without abrupt changes in level. The fields should be planted with clover, short-variety grasses, or alfalfa; and no stock-grazing privileges are granted. Very often three or four parcels of land are rented and thrown together by the removal of fences, hedges, ditches, and the like. In the farming section of the Middle West it is comparatively easy to obtain intermediate fields without having to do much clearing, grading, or conditioning of fields. In the South and West considerable improvement and construction work has been found necessary. Fields are licensed on the basis of 2 to 5-yr. rental periods, the license to remain in force thereafter subject to 6 months' notice of revocation by either party. Availability of commercial power and telephone lines, and the proximity of good highways, railroads and communities are highly important in selecting proper intermediate fields, but safety of flight receives the first consideration.

Sites for the erection of beacon lights are selected approximately 10 miles apart on a straight airline between intermediate fields, so far as practicable, and consist of plots 60 x 60 ft. Availability of power, visibility from one beacon to another, and prevention of collision with obstructions, buttes and side hills are the important factors to be considered in locating beacon sites.

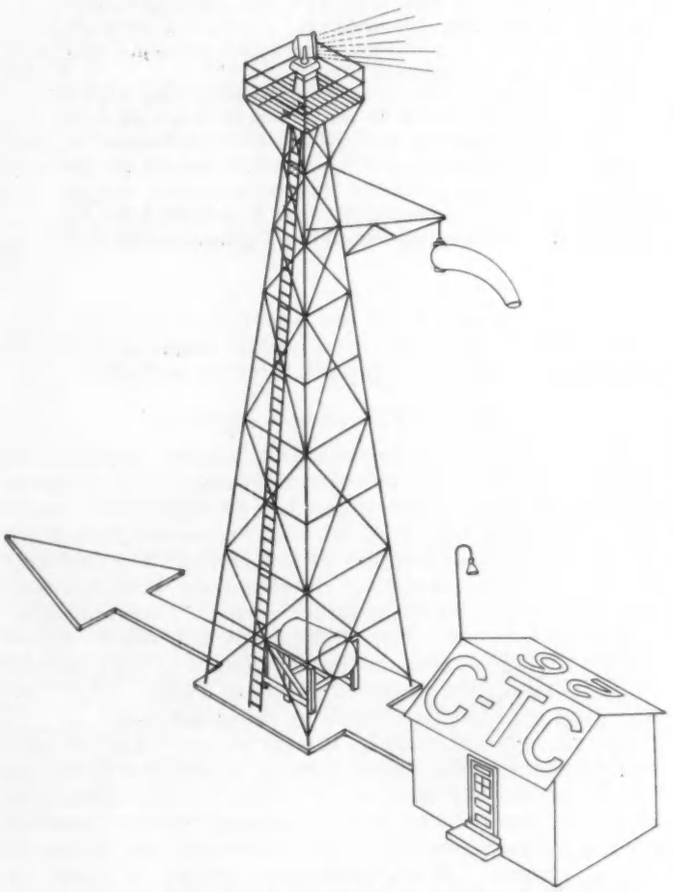


FIG. 1—A TYPICAL BEACON ON NATIONAL AIRWAYS

All Beacon Sites and Intermediate Landing-Fields Are Ground-Marked by an Arrow That Is Painted Yellow and Points in the Direction of the Route. Revolving 24-In. Beacons Are Located at Intervals of Approximately 10 Miles. Commercial Electric Current Is Used Where Available; Otherwise, a Powerhouse Is Erected To Form the Feather End of the Arrow, and Duplicate Generating Sets Are Installed. Letters Painted on the Roof of the Powerhouse Designate the Route, and Figures Show the Beacon Number, Expressed in One-Tenth of the Distance in Miles from the Principal City. Near the Top of the Tower Is a Bracket Carrying an Orange-Colored Wind-Cone, Which Is Illuminated at Night by a Reflector That Revolves with the Cone as the Wind Shifts

GROUND MARKERS FOR DAY FLYING

All beacon sites and intermediate fields are ground-marked for identification from the air. An arrow 56 ft. long is laid out on the ground at the base of the beacon tower and points along the direction of the course. The arrow is painted chrome yellow to give it the greatest visibility and carries a beacon number for identification, painted black in 6-ft. letters. Beacon numbers are based on mileage from the terminal city, the number assigned being the mileage with the unit digit omitted. Where powerhouse buildings are erected, they form the feather end of the arrow as shown in Fig. 1.

The route designation is based on the first letters of terminal cities. It will therefore be seen, from the letters C-TC on the powerhouse in Fig. 1, that the beacon is on the Chicago-to-Twin Cities route, located about 260 miles from Chicago. The arrow points the direction of the route from Chicago to St. Paul and Minneapolis. This is a rational system that requires no maps or other published data for identification and use.

Beacons at intermediate fields are likewise ground-marked. The field can be identified from the air by a circular band 50 ft. in diameter at the intersection of runways, with indicators laid out radially to the outside of the circle pointing out the direction of the runways. The outline of the intermediate field is marked by 3-ft. circles at the bases of the boundary lights. The ground-markers are of crushed rock, gravel, or screenings laid in flush with the ground and whitewashed to show plainly from the air.

AIRWAYS LIGHTING FOR NIGHT FLYING

The Air Mail initiated and demonstrated the practicability of night flying on the New York City-to-Salt Lake City section of the Transcontinental Airway, and the lighting system adopted by the Department of Commerce was based on the experience of the Air Mail. Revolving 24-in. beacons located approximately 10 miles apart are used. Many improvements have been made in the last year, based on the extensive experience and the practice of the Lighthouse Service in marine lighting. The 24-in. revolving beacon does not meet all the requirements of lighthouse practice, which may in a measure account for the divergent views freely expressed among pilots regarding the lighting of airways. The requirements of a marine light may be summarized as follows:

(1) Adequate candlepower for the range required
(2) A distinctive characteristic for identification
(3) Flashes of not less than 3/10-sec. duration to fully register in the eye of the observer
(4) Proper frequency of flashes to keep the position fixed on the horizon
(5) A luminous period of not less than 10 per cent of the eclipse period

The 24-in. revolving beacon is of adequate candlepower in comparison with competitive lights. A distinctive characteristic has been achieved by the use of supplementary lights that are made to flash numbers agreeing with the numbers of the beacons, thereby identifying each airway beacon and fixing its location. The flashing mechanism is attached to the vertical shaft of the revolving beacon and synchronizes the auxiliary light with the flash of the beacon. The chart in Fig. 2 shows the characteristics adopted.

On the Pueblo-to-Cheyenne airway and the Atlanta-to-

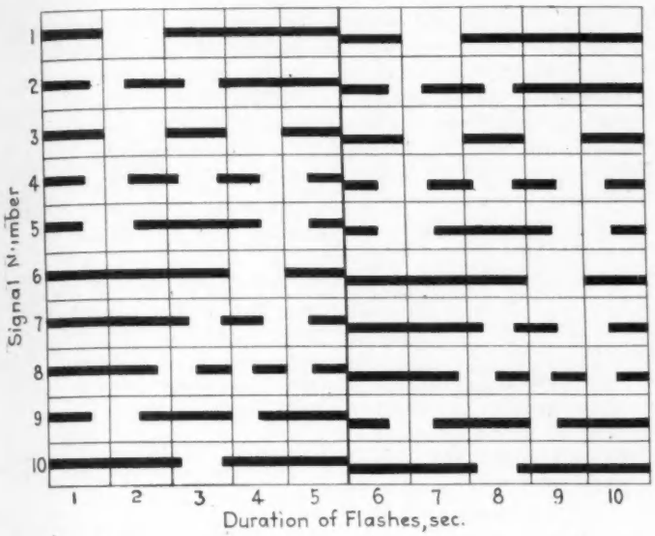


FIG. 2—CHARACTERISTIC SIGNALS FOR AUXILIARY BEACON-LIGHTS

Supplementary Lights Flash the Numbers of the Beacons To Identify and Fix the Location of Each Beacon. The Flashing Mechanism Is Attached to the Vertical Shaft of the Revolving Beacon and Synchronizes the Auxiliary Light with the Flash of the Beacon. The Chart above Shows the Duration, in Seconds, of Intermittent Flashes Identifying 10 Different Beacons

New York City airway the auxiliary lights are projector lights, as shown in Fig. 3, pointed along the course. This arrangement has the advantage of directional characteristics, increased frequency of flashes on the course, and an adequate luminous period, thereby meeting all the requirements of established marine practice without sacrificing any of the merits of former aeronautical lights. A number of improvements tending to increase reliability have been made, including a commercial lamp-exchanger of guaranteed performance, shown in Fig. 4, and improvements in design and materials that have produced better operation and reduced the weight to less than 200 lb.

FAILURE OF CURRENT GUARDED AGAINST

Use of commercial power is resorted to wherever practicable. Pole line-extensions of 2 and 3 miles have been found economical and advantageous. In other places engine-driven generating-plants of 2-kw. capacity are installed. Duplicate sets have been found necessary to obtain the desired reliability, and it is now the practice to install one fully automatic set that operates in the event of failure of the service plant. Fig. 5 shows the wiring diagram of an airway beacon. The wiring is run in rigid conduit in conformity with the National Board of Fire Underwriters' rules.

A wind cone is mounted on a bracket extending from the side of the tower and is lighted internally to make it visible at night. The fabric is open-weave muslin, dyed a bright orange to increase visibility. The light is mounted in a weatherproof socket and is stationary, a reflector moving around with the wind-cone frame to direct the light into the wind cone. The lighting system is controlled by an astronomic 13-jeweled motor-wound clock that makes and breaks 40 amp. of current and switches the lights on at sunset and off at sunrise. All switches, meters and instruments are mounted in galvanized weatherproof cabinets. The standard airway-tower is 51 ft. high, of light galvanized-steel construction with a rigid ladder and 6-ft.-square platform, all designed for the convenience of the airways mechanician and caretaker who services the lights. The tower is designed for a 1300-lb. superimposed load and a wind velocity of 70 m.p.h. Fuel-oil storage tanks of 550-gal. capacity are installed at the beacons.

BOUNDARY LIGHTING OF INTERMEDIATE FIELDS

Intermediate fields are lighted with a boundary lighting system using 110-volt multiple circuits. Parkway duplex No. 10 cable is laid in a trench around the field, with an outlet box at each light standard. The lights are spaced about 300 ft. apart. Fig. 6 shows the boundary-light standard with its special weatherproof fitting and holophane globe. Green range-lights are installed to show the best approaches to runways, and red lights are installed on obstructions. Fig. 7 shows the method of mounting obstruction lights.

Simplified practice and complete standardization have been carried into effect. All circuits are of 110 volts, which reduces the number of motor types, the stock of lamps, and the respective voltages to a minimum. All apparatus is designed for interchangeability of units and for the minimum number of spare parts to be carried for servicing the lights. An airway mechanician is placed in charge of a section of airway and is provided with a 1¼-ton panel-body truck fitted with a complete set of tools and spare parts to meet any emergency repair-job encountered by the substitution of complete new units. The defective parts are sent to the shop for overhauling.

Considerable experimental and development work has been undertaken in the improvement of apparatus, and a number of different types of beacon are on test. A mirror investigation and comparative tests of color screens and neon lights are being made at the Bureau of Standards. Acetylene blinker-lights have been improved by the use of cluster burners, thereby materially increasing the candlepower in excess of competitive lights

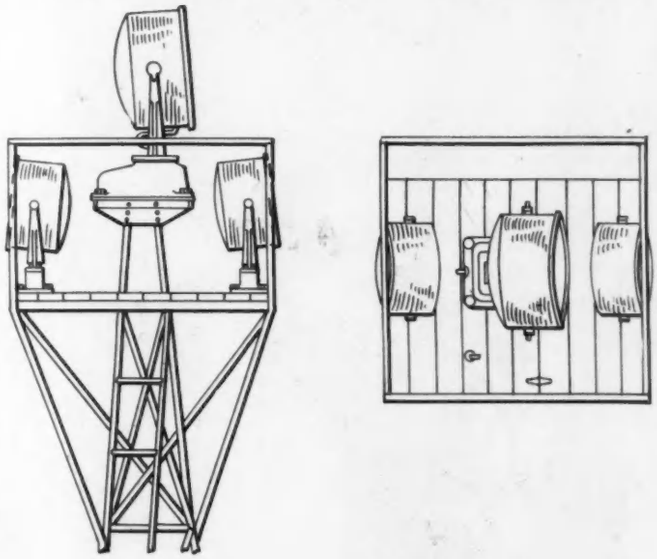


FIG. 3—REVOLVING BEACON, WITH COURSE-LIGHT PROJECTORS, IN ELEVATION AND PLAN

Below and to Right and Left of the 24-In. Revolving Searchlight Beacon Are 18-In. Flood Lights with Spot Mounting. The Flood Lights Are Stationary and Have Their Axes Parallel with the Airway Course. To One Side of the Lamps Is a Cabinet for Housing the Electrical Equipment for Flashing the Flood Lights. This Arrangement Gives the Directional Characteristic, Increased Frequency of Flashes on the Course and Adequate Periods of Illumination

where this type of lighting is found necessary to supplement the higher-powered lights by closer spacing.

Radio for Bad-Weather Flying

Air commerce will demand a high degree of flying efficiency and completed trips on scheduled time. Airplanes can fly in bad weather if the pilot can know his position and altitude at all times and be assured that conditions will permit landing upon his arrival at the terminal field. Radio will serve to increase the flying efficiency.

A radio equisignal range-beacon for aircraft was established at Hadley Field, New Brunswick, N. J., and some experimental work has been completed with the commercial development of a small airplane receiver suitable for single-pilot-operated Air Mail planes. Another radio beacon was installed on the Transcontinental Airway at Bellefonte, Pa., by the Bureau of Standards, and experimental development of suitable radio equipment is under way. A third radio-beacon installation at Cleveland is contemplated which will make it possible to carry on experimental work under operating service-conditions.

Safety of air navigation requires that information regarding landing and weather conditions be made available to air pilots approaching terminal fields, together with periodic information as to changes in barometric pressures at points of known elevation for adjustment of the altimeter while in flight. Installation of radio telephones to communicate this vital information to aircraft in flight is contemplated.

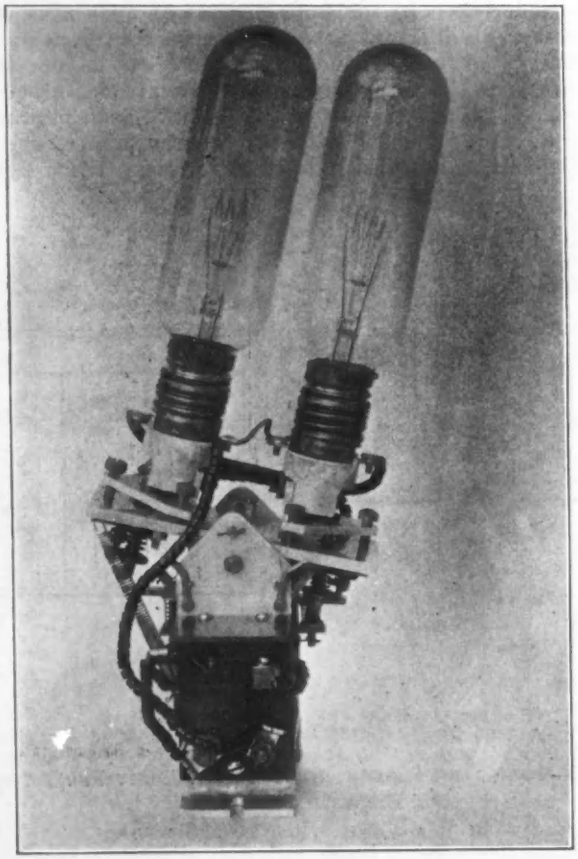


Fig. 4—Automatic Lamp-Changer for Revolving Beacon
This Automatically Switches-On a Reserve Incandescent Lamp if the One in Use Goes Out

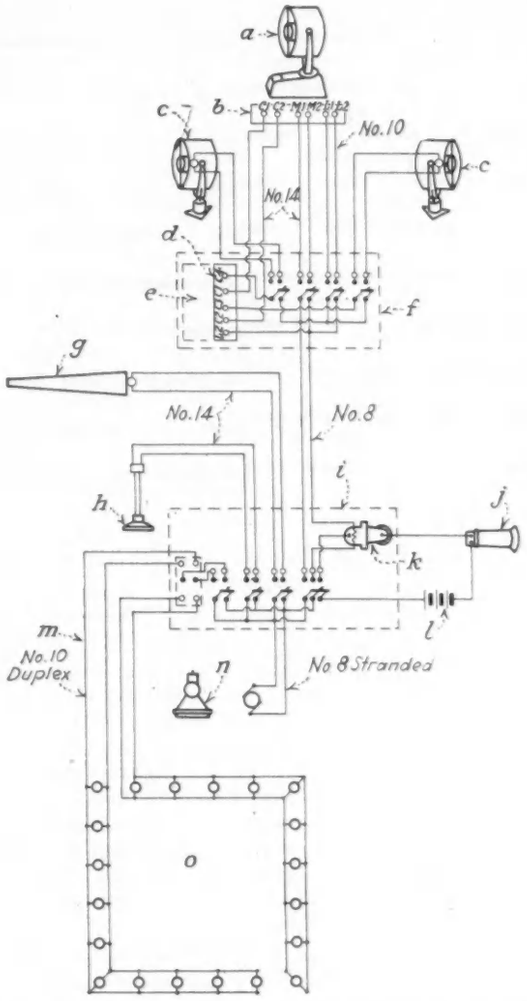


Fig. 5—Wiring Diagram for Beacon and Boundary-Lighting System at Intermediate Fields Using an Engine Generator-Set

a Designates the Revolving 24-In. Sperry Beacon; *b*, the Beacon Terminal Strip; *c*, the Course Auxiliary Flashing Lights; *d*, the Mercury Flasher; *e*, the Flasher Terminal Strip; *f*, the Weatherproof Cabinet on Tower Platform; *g*, the Wind Cone; *h*, the Powerhouse Flood-Light; *i*, the Cabinet in Powerhouse; *j*, the Electric Horn; *k*, the Relay; *l*, the 8-Volt Battery; *m*, the Lead-Covered or Parkway Cable; *n*, the Lighting Plant in Powerhouse; and *o*, the Emergency-Field 15 to 25-Watt Boundary Lights, as Specified. All Wire Sizes Are in American Standard Wire-Gage. Current Is Furnished by a Gasoline-Driven 110-Volt Direct-Current Lighting Plant

Weather Reports and Communications

The Air Commerce Act of 1926 provides that the chief of the Weather Bureau shall furnish weather reports, forecasts, warnings, and advices as may be required to promote the safety and efficiency of air navigation in the United States, particularly on civil airways designated by the Secretary of Commerce. In connection with this activity, the Weather Bureau has established 34 upper-air meteorological stations, many of which are located at airports. Weather data collected throughout the United States are transmitted to the Weather Bureau offices at 8 a. m. and 8 p. m. These data, together with the information obtained from the upper-air stations, enable the Weather Bureau to prepare forecasts of flying conditions. These forecasts are furnished to airports to be available to pilots before taking off.

To make available to the Weather Bureau forecasters information regarding local storms, fogs, and changes of

weather along the airways, a communications system is being established that will enable the airways personnel to furnish the desired data. On June 30, 1927, 28 airways weather-reporters along the Transcontinental Airway were supplying data to terminal fields This airways weather-service will be extended to other routes. An air pilot who is qualified as an aerologist has been detailed to coordinate the weather service and communications, thus making the airways weather-service available to the air pilots for the safeguarding of life and property. Along the Transcontinental Airway, 17 radio stations provide the means of communication for exchange of weather information and to report the arrival and departure of airplanes over the airways, the total weight of cargo, number of passengers carried, and to transmit emergency messages for the safety of air navigation. This system, which will be extended as rapidly as funds permit, provides fast communication, which is essential in connection with air transport. On newly established airways, weather information and forecasts are exchanged between terminal fields by telephone and telegraph.

Organization and Administration

For the construction, maintenance and supervision of airways, the airways division was established in the Lighthouse Service, under the direction of a chief engineer acting as contact officer with the Assistant Secretary of Commerce for Aeronautics. The activities of the airways division have been divided into three sections, covering administration, extension and construction, and maintenance of airways. There are 16 licensed air pilots and 12 engineers in the extension and construction section. The maintenance of airways is accomplished by the expansion of the district offices of the Lighthouse Service. Work in connection with air-navigation facilities has been assigned to lighthouse districts as follows:

Third Lighthouse District, Staten Island, N. Y.—Airways from Boston to New York City and from New York City to Bellefonte, Pa.

Tenth Lighthouse District, Buffalo—Airways from Bellefonte, Pa., to Bryan, Ohio.

Twelfth Lighthouse District, Milwaukee—Airways from Bryan, Ohio, to Omaha; from St. Louis to Chicago, and from Dallas, Tex., to Chicago.

Eighteenth Lighthouse District, San Francisco—Airways from San Francisco to Reno, Nev.; Los Angeles to Salt Lake City, and Los Angeles to San Francisco and Redding, Cal.

One additional office was established at Salt Lake City for the maintenance of airways from Omaha to Reno, from Salt Lake City to Pasco, Wash., and from Pueblo, Colo., to Cheyenne, Wyo.

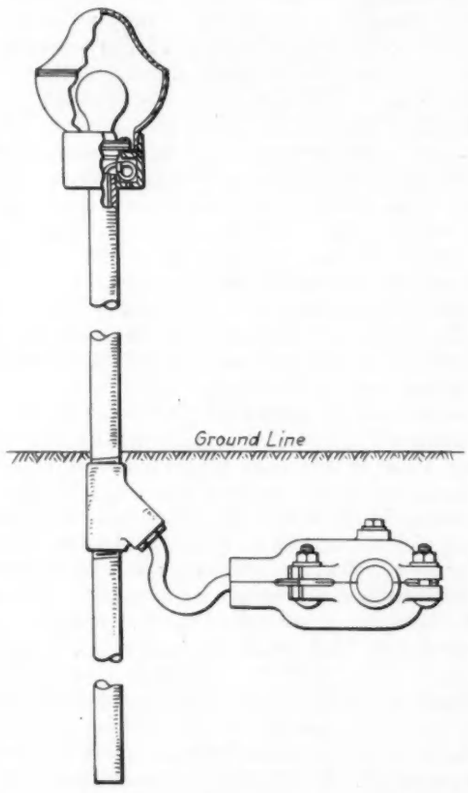


Fig. 6—Boundary-Light Standard for Intermediate Field

The Standard Is of 2-In. Galvanized Conduit 4 Ft. 3 In. Long Set 2 Ft. into the Ground and Carries at the Top a Standard 10 or 15-Watt Incandescent Lamp Enclosed in a Clear, Green or Red Holophane Globe. Drain Holes Are Provided in the 1-In. Fitting That Supports the Globe. No. 14 Duplex Lead-Covered Cable Passes Down from the Lamp through the Standard to a Three-Way Underground Joint-Box Packed with Sealing Compound

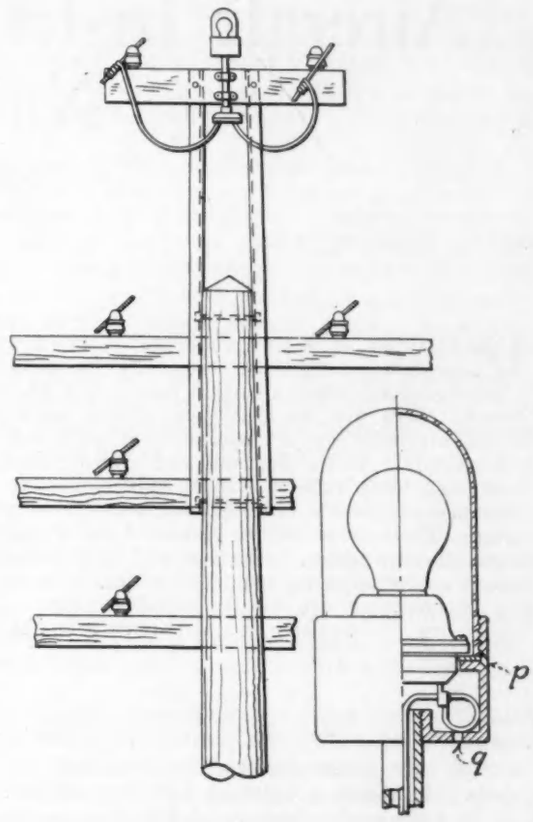


Fig. 7—Obstruction Light and Method of Mounting

The Lamp Is Enclosed in a Corning-Light Red Globe and Is Supported in a Lovell Boundary-Light Fitting, as Shown in One-Half Cross-Section in the Detail Drawing. Water Drain-Holes Are Shown at *p* and *q*. On Telephone and Telegraph Poles, the Obstruction Light Is Supported on a Cross-Arm Bolted to a Pair of Angle-Iron or Yellow-Pine Uprights Bolted to the Top of the Pole. The Supporting Cross-Arm Carries Insulators for the Current for the Light

Aircraft Instruments for Oversea Navigation

By Victor E. Carbonara[1]

Aeronautic Meeting Paper *Illustrated with* Photographs

DIRECTION of motion and rate of speed are the sole data needed for determining the position of a moving object after a certain period of time, but at present there are no absolutely precise instruments on an airplane for accurate determination of these two factors. Radio beacons and radio goniometric apparatus, when sufficiently light and compact to make their use practicable on airplanes, still lack sufficient range. Their reliability is impaired by atmospheric electrical phenomena, by fading and by peculiar conditions encountered in certain localities. The sextant and chronometer are always reliable when celestial bodies are visible, and the apparent complicacy of their use should not be a deterrent to a sane endeavor to make general their practical application for long oversea flights.

Factors that constitute the unsatisfactory features of the navigating instruments now available for aircraft are enumerated and discussed by the author, who outlines the present methods of using the various types of instrument and comments upon their practicability for oversea position-finding. In his opinion, the greatest incentive to the development of better instruments for aircraft navigation will be furnished by an increased active interest taken in their use by aviators in general.

POLAR coordinates are sufficient, when exactly known, to determine the position of a moving object at any instant after its departure from a known pole. In plane navigation covering limited territory, it is sufficiently exact to define the position of any point as a function of distance and direction, the distance being measured from a certain known point and the direction being referred to the geographic meridian. When very long distances are considered, the sphericity of the earth must be taken into account; but, even then, the shortest line connecting the point of departure and that of arrival can be divided into comparatively small portions, each of which can be considered as a vector and expressed as a function of distance and direction.

Unfortunately, the polar coordinates that define the instantaneous position of an airplane in flight are not perfectly measurable with present instruments, the compass in its various forms being the only instrument capable of indicating direction and there being no reliable instrument to record distance or to measure ground speed exactly. For it must not be forgotten that an airplane moves in a moving element and that knowledge of its absolute velocity cannot be had without referring to fixed points of known position.

Complexity of Aircraft Position-Finding

When considering an instrument or a group of instruments designed to furnish the necessary data with the precision that is desirable in position finding, the complexity of the problem appears evident in view of the necessity for integrating the acceleration of the craft due to propulsion from its own engine, to gravity, to air currents and the like, the horizontal components of which are the only ones to be taken into consideration in direction and distance recording.

Magnetic compasses are the only ones to find place in an airplane, their lightness and compactness being the prime reasons for their choice in place of gyroscopic instruments. First considering those of more orthodox pattern, one type of which is shown in Fig. 1, departing only in shape and dimensions from marine compasses, difficulties of installation are a very serious obstacle to their proper functioning. Necessarily, they must be installed well within the range of vision of the pilot, and therefore in proximity to the engine. Magnetic disturbance and vibration, the latter not always eliminated by elastic anti-vibration mounting, are the source of endless trouble. Bad performance of the compass, irrespective of magnetic disturbance, is nearly always traceable to vibration, the latter inducing oscillation or rotation in the magnetic element. If this does not happen, there is always the possibility of having a dull compass-pivot and consequent incorrect indication after a short period of service. Oscillation of an airplane about its three axes is the cause of uncertain reading of the compass, the indication of which must therefore be regarded as approximate.

The earth inductor compass offers several advantages when compared with the foregoing type of magnetic compass. Vibration will in no measure affect the magnetic element, which is a generator, such as shown in the central view of Fig. 2, and it is rather easy to mount the indicating element shown at the left so as to make it free from vibration effects. The controller is shown at the right. Rolling and pitching of the craft have very little effect on the reading, and acceleration forces are readily dissipated due to high damping in a quick period of precession.

The "null" method of indicating the correct heading is far less tiring on the eye than is the reading of the graduations of a compass rose, and it permits more accurate steering. The pilot does not receive verbal instructions from his navigator as to the heading he must maintain, but the navigator himself sets the desired heading on the controller. The convenience of this feature can be appreciated better if we consider an airplane in which the navigator sits in a separate compartment, or if we look upon the navigator as the sole arbiter of navigation. But, even at its best, the compass indicates only the direction of the longitudinal axis of the airplane, and not the direction of its motion. The latter is determined after correcting the compass indication for drift.

[1] Assistant chief engineer, Pioneer Instrument Co., Inc., Brooklyn, N. Y.

Determination of Drift

Correction for drift is obtainable by observation with one of the instruments designed for that purpose, such as that shown in Fig. 3. These bear various trade names, but all are based on the same principle; that is, observation of relative apparent motion of a still object.

Drift indicators are very important auxiliaries in determining the direction of motion of the airplane, taking into account the lateral displacement caused by the wind.

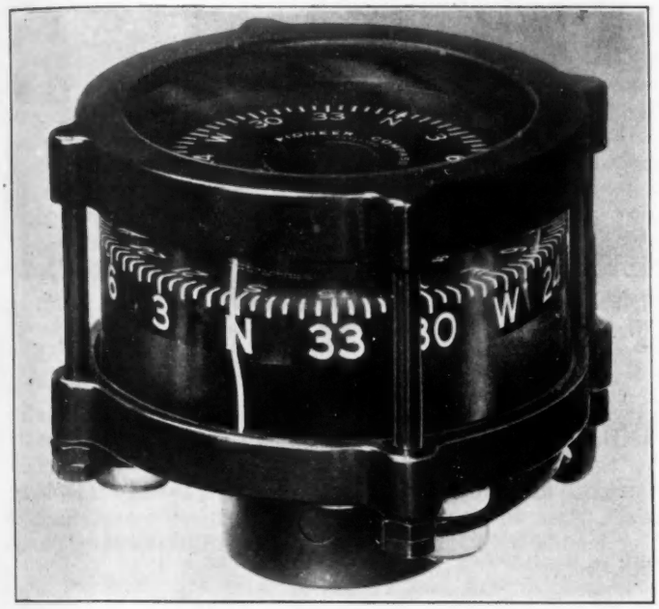


Fig. 1—Type of Magnetic Compass Used in Aircraft

The Lightness and Compactness of the Magnetic Compass Constitute the Prime Reasons for Its Use in Aircraft in Place of Gyroscopic Instruments

They are generally equipped with means for determining the ground speed, be it by observing the apparent angular rate of motion of a fixed object, and correlating this motion to the altitude of the craft, or by determining graphically the wind vector and finding the sum of this and the air-speed vector as indicated by an instrument designed for the purpose.

The speed and drift meter made by the company I represent belongs to the first type, and is preferred because of its simplicity. An open sight vane is oriented in coincidence with the apparent motion of a fixed object on the ground. By recording the elapsed time between passages of the observed object under two cross-wires, the distance between which is set as a function of the altitude of the craft, the ground speed of the craft can be learned so long as the precise altitude is known. Calculation is eliminated by providing a stop-watch having special scales which show the speed directly.

A drift indicator of any type cannot always be employed efficiently in oversea navigation. The absence of sufficiently well defined and relatively fixed points on the surface of the sea makes it necessary to drop smoke bombs or flares, which burn as they float on the water and develop abundant smoke or an easily visible flare. But it must be observed that, although an object dropped from an airplane and possessing the airplane's velocity should fall almost directly underneath it, this is not true when a light and non-streamlined smoke bomb or flare is dropped overboard. Such objects lose their horizontal speed very rapidly as they leave the airplane and ordinarily hit the water well astern of it. Although an object sighted astern will furnish valuable information relative to drift, it is almost valueless for measuring speed because its vertical angle to the airplane varies very slowly and is greatly affected by the pitching motion of the craft.

Conditions of illumination also play a great part in the efficacious use of these navigation auxiliaries. With the sun astern, the visibility of a flare or smoke bomb will be reduced greatly or altogether blotted out by the glare of the light reflected from the water; or the smoke will be spread rapidly and thinned by a strong wind; or the color of the waters, under certain conditions of illumination, will match that of the smoke so that the smoke is not discernible. It follows that speed measurements over the sea are rather difficult and not always possible. Thus we lose one of the elements necessary to define aircraft position, and must then rely on direction alone. But direction is not always known with sufficiently exact approximation; for, even if the compass be excellent, the drift is not constant, the piloting errors are unknown and, if the flight is long and the target is small, there are very serious possibilities of getting lost. Navigation by dead reckoning alone should not therefore be attempted for long oversea flights, even if the airplane be equipped with a reliable and well-corrected compass.

Position Finding by Radio Signals

Radio apparatus certainly will develop to such a degree of perfection that position finding on long flights will be possible by its use; but, for the present, even if

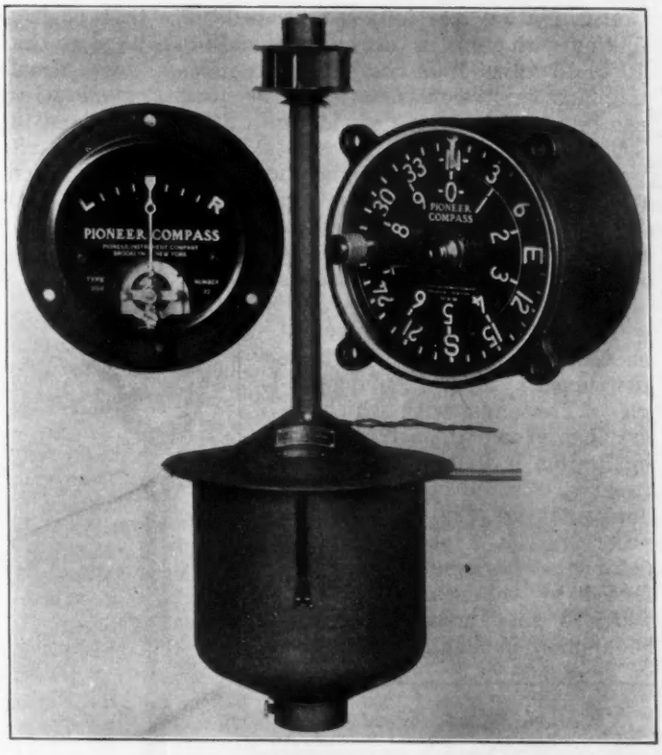


Fig. 2—Earth Inductor Compass

Several Advantages Are Offered by This Type of Compass, Compared with the Magnetic Compass. Vibration Will Not Affect the Magnetic Element, Which Is a Generator Such as Is Shown in the Center and Is Driven by the Impeller at the Top, This Being Turned by the Force of the Air; and the Indicating Element Shown at the Left Can Be Mounted so That It Will Be Free from Vibration Effect. The Controlling Element Is Shown at the Right

we do not consider the comparatively short range of aircraft radio-apparatus, there are other reasons why radio alone should not be relied upon. Atmospheric conditions when radio reception is impossible are too frequent. During a severe electrical storm, an airplane can lose receiving contact with a radio beacon and be blown out of its range. Contact with the beacon sending-station cannot be regained after the storm has subsided, unless the position of the airplane be known.

Use of Radio Goniometric Signals

Radio goniometric apparatus would solve the problem, provided the airplane can make itself heard by two radio goniometric stations with sufficient intensity of signal to make the obtaining of accurate bearings possible. Even then, the location of the two stations may not be such as to furnish two direction-lines that cross at an angle near enough to 90 deg. to render the probable error of position, due to errors in measuring the angles, small enough to be acceptable. Let this be said not to minimize the enormous importance of radio apparatus for oversea navigation but rather to discourage any tendency to make of radio the sole method of position finding at sea. Although, in connection with astronomical methods, radio would furnish what is necessary to find the aircraft's position under any circumstances, reliance on radio alone might prove dangerous.

Astronomical Methods of Navigation

When celestial bodies are visible, the sextant and the chronometer, having a total weight well under 5 lb., represent the most effective equipment for position finding with tolerable accuracy. Modern methods of astronomical navigation are indeed so expeditious that position finding with sufficient accuracy should not take more than 10 to 15 min. It is true that this involves some simple trigonometric calculations; but the necessary operations can be learned by rule of thumb in a short time and the lack of knowledge of theoretical principles ordinarily would not interfere with the successful process of position finding. Some of the available tables are so simplified that all that is needed to render them comprehensive is to rechristen them with a less abstruse name.

The sextant, and the octant shown in Fig. 4, are portable instruments for measuring angles. The angle with which we are concerned in astronomical navigation is that subtended between a celestial object and the horizontal to the eye of the observer. To a seagoing navigator the horizontal is represented by the sea horizon, to which a small correction must be applied depending upon the elevation of the eye above the sea level. As the height of the eye increases, the correction increases and, with it, the radius of the visible horizon is lengthened. The horizon loses definition very rapidly as the airplane rises, even in clear weather, and on most occasions the sky blends with the sea without showing a definite parting line.

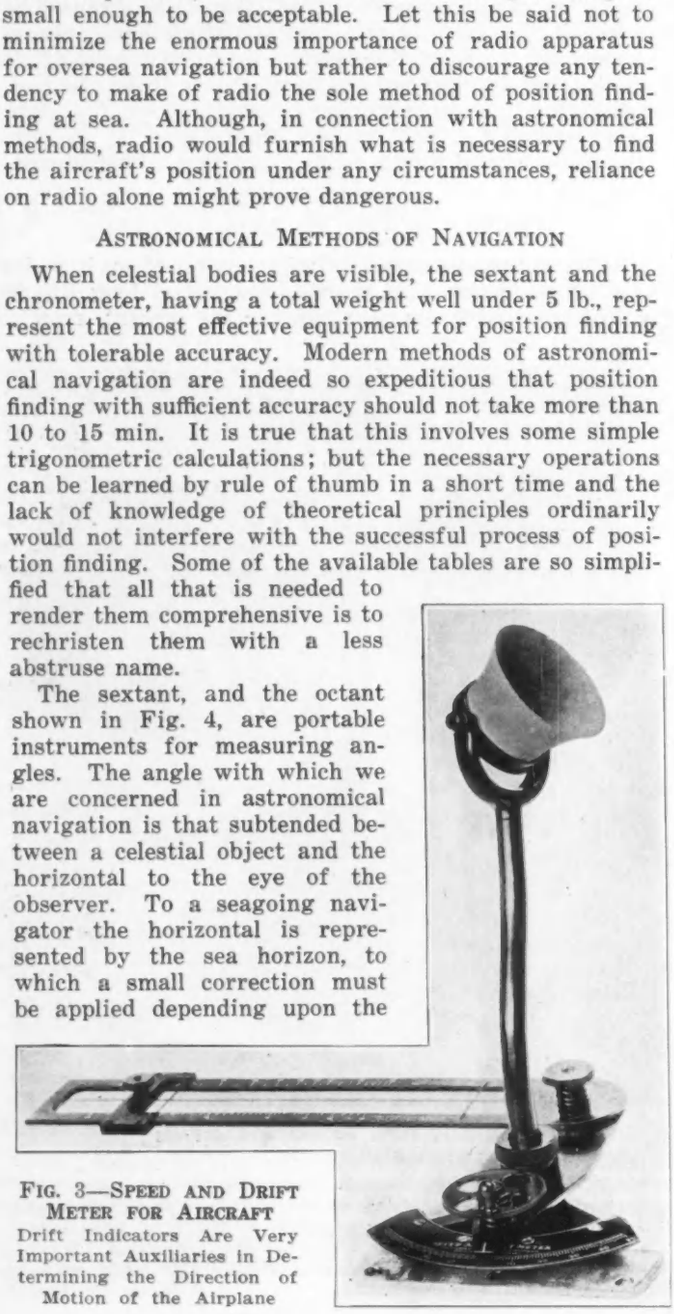


Fig. 3—Speed and Drift Meter for Aircraft
Drift Indicators Are Very Important Auxiliaries in Determining the Direction of Motion of the Airplane

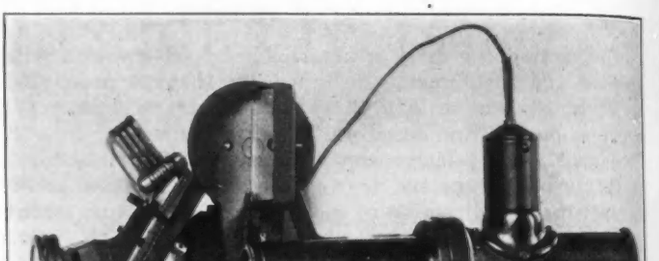


Fig. 4—Octant for Astronomical Position-Finding
When Celestial Bodies Are Visible, a Sextant and a Chronometer, or an Octant and a Chronometer, Represent the Most Effective Equipment for Position Finding with Tolerable Accuracy

The natural horizon cannot be relied upon for aircraft observations, and it is therefore necessary that aircraft sextants be equipped with artificial horizons of such nature that they can be used on an airplane without too great an error. There are various solutions of the problem, such as the use of a bubble level, a simple pendulum, or a gyroscopic pendulum.

Determination of Horizon

The bubble-level type of artificial horizon seems to be the best. It is light, compact, well damped, quick and accurate. Acceleration of the airplane will disturb any gravity-controlled apparatus; therefore, artificial horizons of any type will be disturbed by the turning, pitching and varying speed of the airplane. The magnitude of the consequent errors depends largely on the skill of the pilot and on that of the observer. It is very difficult to offer any conclusive data, because comparatively few fliers have tried to use a sextant in flight and fewer yet have made a constructive report on their success. But it is safe enough to consider an error of 30 min. as a rather large one for a series of four observations of the same object, made in quick succession, by a fairly skilled operator. In terms of accuracy in position finding, this means a probable position-error of about 30 nautical miles, or 35 statute miles, which is very small indeed when long-distance oversea flights are considered. When two celestial bodies are observed, and the navigator is not sure that his sights are less than 30 min. in error, the airplane is known to be within a square having sides 70 miles long, the position of which is perfectly defined.

To explore the foregoing square so as to pass within less than 20 miles from any point of its area is a matter of 1 hr. 40 min. for an airplane having a cruising speed of 100 m.p.h. Supposing that the target is so small as to be invisible under certain conditions from any point

farther than 20 miles from its center, it will require a maximum of 1 hr. 40 min. to find it. We have supposed the navigator to have made an error of 0.5 deg., averaging four readings. According to the theory of errors, these 30 min. represent the probable error for a single reading divided by the square root of the number of observations. This, in the supposed case, makes the error for a single reading 1 deg. so that, by extending the number of sights to nine, the average error probably will be reduced to 20 min.

Analyzing the causes tending to produce 1 deg. of deviation in the direction of apparent gravity, we find that a longitudinal acceleration of 0.6 ft. per sec. per sec., or a turn of the airplane at the rate of 13 deg. per min., will cause this deviation, the former in the longitudinal and the latter in the transversal plane. But, supposing the airplane to be in level-flying attitude, forces producing such longitudinal acceleration are necessarily of very short duration, and their effect on a quick period and highly damped artificial horizon cannot lead the observer to large error. In fact, experience proves that sights taken with the axis of the instrument in the longitudinal plane of the airplane are the most accurate.

When making observations athwartship, centrifugal force will have its maximum effect on the readings. However, a turn at the rate of 13 deg. per min. is noticeable on a sensitive turn-indicator, and a skilful pilot can avoid it easily. With care and skill on the part of pilot and observer, the probable error, in calm weather, can be kept within 10 min. Even when the weather is rough, it is nearly always possible to find an altitude at which the airplane rides smoothly; at any rate, when a large error is feared on account of unfavorable weather conditions, the number of observations can be increased and the mean of these used in making the necessary calculations.

Navigation instruments and, in general, aircraft instruments, are far from being perfect. Experimenters are constantly devoting their ability to the development of better devices, and it will be extremely helpful to their efforts if those among the aviators who desire to become proficient in the art of navigating will relate their experiences and offer constructive criticism.

Metal Research Problems

AMONG the multitude of research problems concerned with metals and alloys is the ever-present one of reducing the stupendous losses resulting from corrosion. We already have a stainless steel, which has proved a boon to the housewife in table cutlery and suggests the possibility of developing a sterling-silver alloy that will not tarnish. These are relatively small matters as compared with the corrosion of metals in structures and equipment. The properties of chemically pure iron indicate a wide field of usefulness for the metal, provided it can be produced in quantity at low cost. It is silver-white, soft, malleable, and highly resistant to rusting and corrosion.

Aluminum is now produced from bauxite, the native oxide, which is comparatively scarce, whereas clay, the silicate of aluminum, is abundant, widely distributed and very cheap. A method of producing this light and useful metal directly from clay is greatly to be desired and has long been sought. Recent developments in Germany and Sweden indicate that we may be within striking distance of success.

The enormous deposits of chalk and limestone carry approximately 800 lb. of calcium per ton, yet the only industrial use for calcium is in an alloy with barium as an anti-friction metal for bearings. Barium itself, though possessing unique properties, remains little more than a laboratory curiosity. Beryllium has still to find a place in industry, and hafnium, though more abundant than lead, awaits employment. Cobalt is available in quantities far beyond present demands, while tin, on the other hand, can barely meet those made upon it. We need to find new uses for the one and substitutes for the other.—From an address by Arthur D. Little.

Automobile Replacement Demand

REPLACEMENT demand represents, and must continue to represent, a factor of constantly increasing importance in the market for motor-cars. Since 1923 the net annual increase in the number of passenger-cars and trucks in use has steadily declined, not only proportionately, but numerically, while during the same period the output has increased. Although the largest actual increase in the number of cars registered was in 1923, the percentage gain has been declining almost steadily for the last 12 years.

This growth in the importance of replacement means, of course, that the automobile industry must face the prospect of a permanently lower rate of increase in the number of cars in use. At the same time, it indicates that this tendency need not result in any abrupt or drastic change in the rate of motor-car output. In other words, it shows that the "saturation-point" in the automobile market so widely discussed and feared in the past is in reality a saturation process, which has been going on for years and will probably continue indefinitely, with a gradual tapering of the demand for additional vehicles, a gradual increase in the demand for replacements and a slow but sustained growth in the total number of cars in use.

Such a situation can hardly fail to result in greater stability in the position of the industry. Whether motor-car manufacture will ultimately find a level above or below the average output of the last few years, is impossible to foretell. It may, however, be regarded as certain that there is a permanent market for motor-vehicles sufficiently large to maintain the industry in the front rank of the Country's manufacturing enterprises.—*Guaranty Survey.*

Net Profit from Modern Machine-Tools

By George T. Trundle, Jr.[1]

Production Meeting Paper

THE necessity of reducing manufacturing costs to create wider markets and meet competition without a loss has emphasized the importance of keeping a plant well equipped with modern machine-tools. This is a subject that has been neglected, not because the need of modern machine-tools has not been brought to the attention of management, but because, in most instances, the ready cash has not been at hand. The author suggests a means of making the necessary funds available by keeping the reserve for depreciation of machine-tools in a form easily liquidated. He mentions the desirability of devising some formula that will determine the time when obsolete machine-tools should be replaced and urges that some national organization study the subject of reserve for depreciation and budgets for new equipment, thus endeavoring to improve conditions.

An example is cited to illustrate how net profits can be increased by the purchase of a modern machine-tool to replace obsolete machines. The savings were 44 per cent in the case cited, but this does not mean that every replacement need show so large a saving. According to the author, it is, on occasion, good business to purchase new equipment when the saving is as low as 5 per cent. He recommends that mechanical equipment and methods be audited continuously and that, when these audits reveal losses, the defects in equipment and methods be corrected.

WHEN a manufacturer reduces his selling prices to create a wider market for his product his competitor also makes reductions but finds himself operating without a profit and, in most cases, at a loss. The competitor calls a conference of the members of his factory organization and notifies them that manufacturing costs must be reduced. Often the first procedure is to attempt to make labor produce more and, as a professional engineer, I have observed some interesting attempts in this direction.

One of the common ways of lowering cost is to reduce the incentive in the hope that the workman, to maintain his pay the same over a pay period, will accomplish greater production. It is true that during the last few years the productivity of labor has increased materially; but this increase is not because the workman is more efficient or is working harder. On the contrary, it is because management itself has become more efficient in that it plans the work in great detail and furnishes the workman with better tools. The workman can be no more efficient than the machine which he operates.

Machine-tools are back of the great industries that are supplying the wants of the people. How far could we go in any line of industry without machine-tools? Many advantages are possessed by the machine-tools of today compared with those made a few years ago, yet many manufacturers are attempting to meet competition and make a profit without changing their machine-tools.

One of the greatest problems that management has is to determine whether present equipment should be replaced with modern machine-tools and, if so, how the needed capital can be made available. While trying to convince the general manager of a large corporation that he should invest in modern machine-tools, he argued that the machine-tools in his plant had been kept in good repair and were as good today as when he bought them 10 to 20 years ago. As we rode together in his modern high-priced automobile, I commented on the ease with which it drove, its quick pick-up and its hill-climbing ability, all because the vehicle had power, and called his attention to the fact that the machine-tools today have greater power than did the machine-tools of yesterday. They remove metal faster and require less skill to produce a part accurately.

One may say that any machine will produce parts accurately if it is properly tooled. Perhaps it will do so, but it requires great skill on the part of the operator and takes a much longer time.

Machine-Tools Can Create Profits

Why does not industrial management take advantage of the net profits made possible by the use of modern machine-tools? One manufacturer said that he would buy any machine-tool that would pay for itself in 1 year, and another advertises that he will buy any machine or process that will pay for itself by savings in 2 years. But do the buildings which house the industry pay for themselves by savings in 2 years? Fortunately, real estate increases in value in most cases as the years go by, but this is not true of machinery. The manufacturer who will not purchase new machinery unless it pays for itself in from 1 to 2 years is doomed. Competition is bound to "get" him. Such a rule might apply in the case of special one-purpose machines for a product that is liable to change, but should not be applied to standard equipment. Most machine-tools have a very long life. It is possible that they may not be suitable for a large-quantity-production plant after 2 years, but they still are suitable for a smaller job on small-quantity production; therefore, they have a cash value.

Good management should encourage its factory organization to keep the plant well equipped with modern machine-tools. This does not mean that machinery is to be bought without knowing the facts as to what net profits will be gained by such purchase. The problem of the factory organization is to present the net profits that can be earned by the use of the modern machine-tool as compared with one not so modern in such form that the executives of the company will be compelled to make the appropriation. But in most cases the factory organization fails to obtain the funds, not because it has not presented its case well, but because no reliable data are available to guide management in making its decision, either from the viewpoint of savings or from that of having the money available.

Reserve for Depreciation of Machine-Tools

I have devoted much thought to the item known as "reserve for depreciation" that appears in most financial

[1] Consulting engineer, Trundle Engineering Co., Cleveland.

statements. The definition of "reserve" is "to keep in store for future or special use." It is my belief that the accountant who originated the idea of such a reserve had in mind that the money should go into a bank as a savings account, or be left in a form easily liquidated so as to have it available for replacements. As an example, suppose a machine cost $1,000 and the depreciation is 10 per cent per year. At the end of 5 years $500 is in the machine and $500 is credited to the reserve. It is found that a more modern machine is on the market that is 50 per cent more productive, but it costs $1,200. Let us say that the trade-in value of the old machine is $500. The need is for $700 more, $500 of which should be available; but suppose it is not available because the reserve for depreciation has been used as working capital? The condition is then the same as that of the boy who ate the other boy's apple. One boy says, "I want my apple"; and the boy who ate it says, "Let's see you get it." If the $500 reserve were available, only $200 plus tooling-expense would need to come from the capital-expenditure account. Is it not reasonable to expect that the savings the new machine would accomplish should be compared with the $200 additional capital, plus the perishable tools that must be scrapped, rather than with the $1,200 which it costs? Net profits should therefore be computed on the amount of money taken from the capital-expenditure account on a machine replacement, rather than from the entire cost of the machine.

Allowances for Depreciation

Much can be said about the percentage allowable for the depreciation of machinery, and what disposition should be made of the reserve fund. An analysis of a financial statement usually will show reserves for depreciation, but I doubt that any manufacturer has these available in cash. The subject is one that needs the attention of some national organization that will devise a more practical way to guide industrial executives so that they will have at all times available, not only the cash on hand in their "reserve for depreciation," but also a formula applicable to the profitable replacement of machine-tools. When management begins to view the problem from this angle, manufacturing plants will be better equipped and there will be fewer failures resulting from losses through inability to meet competition.

Systematic Modernizing of Equipment

A definite plan of procedure should be established in every plant to provide for the systematic and orderly modernizing of equipment. For instance, once or twice a year a budget should be made which will cover the purchase of new equipment and it should equal the amount of cash held in reserve for depreciation. When a new machine represents an investment in excess of the cost of the original machine, the difference in cost should be charged to capital expenditure.

Numerous other objections are made by manufacturers against the replacement of obsolete equipment by modern machine-tools. A thorough analysis of the subject with a view of reducing the present resistance will have a beneficial effect upon industry as a whole. Many instances exist in which an old machine can be sold for more than its book value. In such cases, the actual depreciation, as demonstrated by the resale price, is far below the percentage set up in the reserve-for-depreciation account. The accentuating of such probabilities to the manufacturers should have a tendency to decrease resistance to machine replacement.

Example of Replacement Method

As consulting engineers we continually find our clients endeavoring to meet competition with machine-tool equipment that is not best suited for their production. A typical example is that of a part which required two machine-tools that for many years had been carried on the books at "no value," there being a reserve of $3,000 in the depreciation account, charged as being their original cost. Machine No. 1 performed operation (*a*) in 0.033 hr.; machine No. 1 performed operation (*b*) in 0.020 hr.; and machine No. 2 performed operation (*c*) in 0.060 hr., a total time of 0.113 hr. A modern machine was available that would perform the three operations in 0.055 hr., thus making a saving on each piece of 0.058 hr. and would require but one operator. Sufficient parts were to be made to keep the new machine busy 9 hr. per day for 280 days per year.

Allowing the operator 60 cents per hr., a saving of $5.39 per day was effected which, for the 280 days, was a saving of $1,509.20 per year in direct labor. The cost of the new machine was $2,200, and that of the tools, $500, a total cost of $2,700. Deducting $350 as the trade-in value of the two old machines leaves $2,350, the actual cost. Subtracting from the $1,509.20 saving per year 20 per cent of the actual cost, or $470, for depreciation, it is evident that there was a net profit of $1,039.20, or 44 per cent. We did not consider overhead in the foregoing figures.

In the example cited, management saw the wisdom of purchasing the modern machine and, fortunately, had the $2,350 available. If the original reserve charged against depreciation for the two old machines, which was $3,000, had been intact, this transaction could have been made and a balance of $650 would have remained which could have been credited as profit.

We know of many instances in which a machine such as the foregoing one would not have been purchased, even though the saving were 44 per cent. The case cited is not an isolated one. We discover them frequently and no doubt will continue to do so until management is convinced that profits are created by modern machine-tools, and adopts a sound universal procedure for the replacement of obsolete equipment.

In conclusion I wish to urge the necessity for auditing machinery and methods constantly, and when the audit reveals losses, proper means should be used to turn those losses into net profits.

THE DISCUSSION

Eugene Bouton[2]:—The method of handling depreciation has been criticised severely by production men because of the fact that the percentage used was an arbitrary or selective amount rather than one based on an actual survey of equipment conditions. It is usually common practice to charge off 10 per cent annually and to set up a reserve to assure replacement when the equipment is beyond further use or more modern equipment would make the present type of equipment obsolete. It is not uncommon to find that, when production requests new equipment, such a reserve fund has been used for other purposes. When we realize that, using the 10-per cent factor, in 5 years we have, according to book value, 50 per cent less equipment to do the same volume and quality of work, it is only logical that production should demand that these reserves be available for replacement

Depreciation is handled very loosely in the majority

[2] M.S.A.E.—Supervisor of time-study, Chandler-Cleveland Motors Corporation, Cleveland.

of manufacturing plants, and fixed percentages are used; but there is a very decided difference in the kind and amount of depreciation on different types of machine. It seems that the cost accountant has not viewed the production man's problems in the manner which would be of benefit to both production and the management itself. It is to management's advantage to have funds available by the setting up of reserve funds to take care of depreciation as it takes place so that, when the obsolete or worn-out equipment is to be replaced, it can be done without creating the impression that capital expenditures are being increased or money is being withdrawn from surplus.

GUY HUBBARD[3]:—The first national meeting of the Machine Shop Practice Division of the American Society of Mechanical Engineers during the New Haven Machine Tool Exhibit was dedicated primarily to this exceedingly important subject of "economics in the machine shop." Executives as well as production men of the Eastern metal-working industries attended in considerable numbers and occasion was taken to bring out very forcefully some plain facts along the line of those which Mr. Trundle has just emphasized so ably.

It has repeatedly been brought to our attention that reserve funds originally set up properly to cover depreciation of mechanical equipment have been diverted to other entirely foreign and often mysterious uses. The inevitable results have been watched carefully and are as follows. In due time operating deficits appear and vain efforts are made to cover these deficits by drawing upon the surplus, which usually contains the money originally set aside for replacing the old machinery now to blame for the deficits. In spite of this treatment the deficits persistently refuse to remain covered, the surplus fades into thin air, and liquidation follows.

While the activities of the American Society of Mechanical Engineers in stirring up interest in this subject have brought out a wide difference of opinion as to just how these accounts should be handled, there is an unanimous agreement that the big task is to sell to those who hold the purse-strings the vital importance of consistent policies of replacement of production machinery. For 2 years the A. S. M. E. has hammered away at this idea editorially, and we believe that every similar organization having publications which reach the executive eye should do likewise. The action of the Society of Automotive Engineers in giving widespread publicity to this paper by Mr. Trundle will be particularly effective in this respect.

[3] Associate editor, machine tools and production department, *Mechanical Engineering*, New York City, and a director of the Machine Tool Congress.

[4] M.S.A.E.—Editor of *Machinery*, New York City.

[5] M.S.A.E.—Advertising and assistant sales manager, Bullard Machine Tool Co., Bridgeport, Conn.

[6] M.S.A.E.—Editor and president, Automotive Abstracts Co., Inc., Columbus, Ohio.

ERIK OBERG[4]:—I have had opportunity to observe some of the methods used in automobile plants in determining whether it is profitable to install a new machine. Some companies determine this in a remarkably accurate and thorough manner. If a paper on this subject could be obtained—one which would be detailed as to the information regarding how these matters are determined—it would be very valuable. By such methods, it is possible to calculate exactly that in a certain number of days at a certain rate of production some particular machine will pay for itself.

MR. BOUTON:—There seems to be no standard method by which the savings effected by new equipment are figured. Each plant seems to have its own method of arriving at the result. Some of these methods have considerable merit, others are incomplete or too much in detail. Recently I have had the opportunity to observe several reports of the V. A. Nielsen Co., on the equipment which Mr. Blanchard represents. What success has he had with these reports and with what degree of interest have they been received by production men?

CHAIRMAN E. P. BLANCHARD[5]:—Our company has used the reports mentioned by Mr. Bouton and finds them very effective. They are correct and are based on an exact survey of conditions that an unbiased engineer finds in plants where our company's equipment is used.

The report is made by the investigating engineer with the consent of the customer. Everything in the report must be known to the user of the machine and agreed to by him. The reports form a basis of sales and advertising appeal; but, although they are backed by the prestige of this nationally known organization of auditing engineers, invariably a production man will question the method by which the facts are determined, rather than to question the facts themselves. This means that there is need for recognition of a standardized method of cost calculations, especially for comparative purposes. The Material-Handling Committee of the American Society of Mechanical Engineers has worked out a formula for cost calculation, and I believe that production engineers should work out a similar formula to enable them to make comparisons. When the facts become available they can apply their own production formulas, and this will obviate argument over the method of accounting. What is wanted is to determine the effectiveness of the machine and the economy it accomplishes.

JOHN YOUNGER[6]:—I concur with Mr. Blanchard that some formula is needed. It seems to me that the manufacturers should be warned by the fact that some of the abandoned farms in New England and the South were abandoned because the farmers did not "plow-in" some of their profits. For this reason the land became unproductive. They should remember that some of the profits must be "plowed-in" continuously, and they should determine what percentage of the profits should be applied in this manner.

Using Truck-Operating Costs To Increase Delivery Efficiency

By A. W. Herrington[1]

Transportation Meeting Paper *Illustrated with* Charts

In line with devising some standard method of recording fleet operating-costs so that they can be utilized comparatively, the author cites a supposed company in the retail dairy business which has a fleet of 30 vehicles, assumes definite monetary values for the several factors constituting the total cost, and analyzes the entire problem in a way to demonstrate the fundamental principles of a comprehensive system of accounting that will make evident all the information sought.

Eight divisions of operating cost are made and the reasons governing this division are stated. An analysis of the cost is then made on a mileage basis, the main items considered being gasoline, oil, tires, repairs and miscellaneous, and it is shown how the costs are adjusted finally so as to include all the items of expense.

The facts and figures specified are all assumed. No attempt is made to indicate the ideal, or efficient, operation. The costs assumed were chosen more to illustrate the method than to represent actual conditions. In conclusion, the author says that the keeping of cost records is a simple matter when all cost factors can be recognized and classified. Carelessness in the consideration of these factors is what leads to difficulty, and this is true particularly in the overhead, or burden items.

DURING the last year the Maintenance and Operation Committee of the Society has had under consideration the problem of getting some standardized method of recording fleet operating-costs in such a manner that they can be used intelligently for comparative purposes. Many factors are involved in a study of this character, and fleet operators are loath to give up the home-made, cut-and-try methods which they have adopted for their own use. In many instances these methods give data of sufficient value for comparative purposes within the particular fleet in which they were collected, but they are of no value for comparison with another fleet in the same line of business in another section of the Country. This paper will not discuss any particular method of collecting data of this character but rather will direct attention to certain basic principles involved and to the interesting information which the proper analysis of these records will develop.

An effort has been made to make the example cited as simple as possible because it is necessary to recognize from the beginning that the man who is responsible for the operation of the average commercial fleet is more often a practical foreman or mechanic than a trained bookkeeper. All vehicle operating-cost figures fall roughly into three classes: (*a*) costs accruing on a time basis irrespective of miles, such as license, taxes, insurance and the like; (*b*) costs accruing on a mileage basis irrespective of time, such as gas, oil, tires and repairs; and (*c*) costs incidental to the employment of vehicle operators, or drivers. The example taken is that of a company in the retail dairy business operating a fleet of 25 1-ton trucks equipped with side-door milk-delivery bodies, each body having a normal capacity of 40 cases of quart bottles. In addition we will assume that in this same fleet there are four spare trucks which are duplicates of the vehicles in regular service, and one shop service-wagon. To obtain the amount of the original investment in one of these vehicles we will assume the following costs:

Chassis	$495
Freight and Delivery	50
Side-Door Milk-Delivery Body	250
Paint and Lettering	100
Extra Equipment, Spare Tire, Bumpers, and Rear-View Mirror	75
Total,	$970

Therefore, each of the vehicles will cost $970 delivered to the company ready for use in the milk-delivery business.

Analysis of Operating Cost

In making an analysis of the cost of operating these trucks, we will use the following division of fixed costs:

(1) License
(2) Taxes
(3) Insurance
(4) Depreciation
(5) Storage
(6) Washing and Greasing
(7) Painting
(8) Overhead

We will assume item (1) as being $10 per truck per year and item (2) as being 2 per cent of the average total investment of $970, or 2 per cent of one-half of $970, which is $9.70 per truck per year.

As to insurance, item (3), the assumption is that the following coverage is carried: Public liability, $25,000 and $25,000 limits; property damage, $1,000 limit; fire and theft; and collision. All these are taken as totaling $125 per truck per year.

The inclusion of depreciation, item (4), in the fixed costs may cause some discussion, but the reason is definite. We will assume a fleet average of approximately 10,000 miles per truck per year, or about 27 miles per truck per day. As mileage in this class of service is relatively low, the time basis for depreciation is the most satisfactory. Assuming 40,000 miles as the economical vehicle life, this means 4 years of service. Including a salvage or junk value of $50 per vehicle at the end of this period leaves a net amount to be depreciated of $970 — $50 = $920. Dividing this over 4 years gives a depreciation of $230 per truck per year.

For housing, item (5), we will assume that 10,000 sq.

[1] M.S.A.E.—Consulting engineer, City of Washington.

TABLE 1—DATA FOR FIG. 1 SHOWING HOW COST PER MILE DECREASES WITH INCREASE IN MILES TRAVELED

Miles per Year	Fixed Cost per Year	Mileage Cost per Year	Total Cost Per Year	Total Cost Per Mile
1,000	$3,438.00	$72.80	$3,510.80	$3.510
2,000	3,438.00	155.60	3,593.60	1.790
3,000	3,438.00	218.40	3,656.40	1.210
4,000	3,438.00	291.20	3,729.20	0.930
5,000	3,438.00	364.00	3,802.00	0.760
6,000	3,438.00	436.80	3,874.80	0.640
7,000	3,438.00	509.60	3,947.60	0.563
8,000	3,438.00	582.40	4,020.40	0.500
9,000	3,438.00	655.20	4,093.20	0.454
10,000	3,438.00	728.00	4,166.00	0.416
11,000	3,438.00	800.80	4,238.80	0.385
12,000	3,438.00	873.60	4,311.60	0.359
13,000	3,438.00	946.40	4,384.40	0.337
14,000	3,438.00	1,019.20	4,457.20	0.318
15,000	3,438.00	1,092.00	4,530.00	0.302
16,000	3,438.00	1,164.80	4,602.50	0.287
17,000	3,438.00	1,237.60	4,675.60	0.275

ft. of garage space is rented to provide for storage, repair, washing, greasing and the like, the cost of this space to be $0.40 per sq. ft., or $4,000 per year. Dividing this by 30—since there are 25 regular, 1 service and 4 spare trucks—gives a cost of $133.33 per truck per year. This cost would be approximately the same in premises owned by the company.

As this company is in the dairy business, cleanliness is a paramount requirement. It must comply with the requirements of the local health authorities, and there is a definite advertising value in having clean equipment in this class of business. Washing and greasing, item (6), is therefore included in fixed cost because every vehicle will be washed every night regardless of the number of miles it runs during the day. We will assume that two men at $30 per week each are employed to wash and grease these trucks. This will make a total labor-charge of $3,120. It is also necessary to consider the ownership cost, repairs, and maintenance of a power-driven washing-machine, soap, sponges, rags, grease, hose, power, lamps, and water, assumed as being a total of $140 per month, or $1,680 per year. Adding to this the labor payroll of $3,120 gives a total of $4,800 per year, or $160 per truck per year.

Painting, item (7), will be done annually regardless of mileage covered. We will assume that all vehicles are repainted annually at an outside shop at a cost of $100 each.

Overhead, item (8), is very difficult to determine accurately, but if proper recognition is given to all items not directly charged against the individual truck under other headings, a fairly accurate estimate will result. We will assume employment of a fleet superintendent at $300 per month. This would be $3,600 per year, or $120 per truck per year. An accounting cost of $5 per truck per month, or $60 per truck per year, is also assumed to cover records, forms, stationery, telephone and the like. We will also add $90 per truck per year for prorated cost of other executive salaries and expenses. The fleet superintendent will also require the use of one of the regular office stenographers for part time. We will charge the operating expense with one-third of the annual salary of one stenographer, or one-third of $1,200 per year, or $400. This equals $13.33 per truck per year. Totaling the foregoing items gives: Superintendent's salary, $120; miscellaneous stationery, $60; executive expense, $90; and stenographer, $13.33, or a total overhead-charge of $283.33 per truck per year. "Overhead" is used here, not in the accountant's technical interpretation of the term, but as the unabsorbed burden of indefinite and indirect charges.

Summarizing all the items of fixed cost per truck, and noting that milk is delivered 365 days per year, we have:

(1) License		$10.00
(2) Taxes		9.70
(3) Insurance		125.00
(4) Depreciation		230.00
(5) Storage		133.33
(6) Washing and Greasing		160.00
(7) Painting		100.00
(8) Overhead		283.33
Total Fixed Cost per Truck	Per Year	$1,051.36
	Per Month	87.61
	Per Day	2.85

Analysis of Mileage Costs of Operation

Mileage costs are based upon an average of 10,000 miles per truck per year. The following items are included:

(1) Gasoline
(2) Oil
(3) Tires
(4) Repairs
(5) Miscellaneous

Regarding the cost of gasoline, item (1), we will assume that this company has its own storage tank and can buy gasoline at tank-wagon price, or say 16 cents per gal. As milk-delivery service requires frequent stops and long periods of engine idling-time, the gasoline-consumption mileage is low. For this case we will assume it to be 8 miles per gal., a cost of 2 cents per mile. Oil cost, item (2), is assumed roughly at 25 per cent of the fuel cost, or ½ cent per mile.

Concerning items (3) and (4) and assuming a cost of $30 per tire and an average life of 10,000 miles, the cost per mile for the four tires would be $120 divided by 10,000, or $0.012 per mile. An additional amount of $40 per truck allowed for tire repairs in this same period makes an additional $0.004 per mile, or a total cost of $0.016 per mile for tires.

We will assume the full-time employment of one mechanic at $50 per week and one helper at $30 per week to maintain these 30 trucks. The total annual payroll for this purpose will be $4,160. Assume also an expense of $1,000 per year for maintenance and replacement of shop tools and the like, and a further flat allowance of $75 per year per truck for parts, or a total of $2,250 per year. Totaling the foregoing costs for labor, for tool

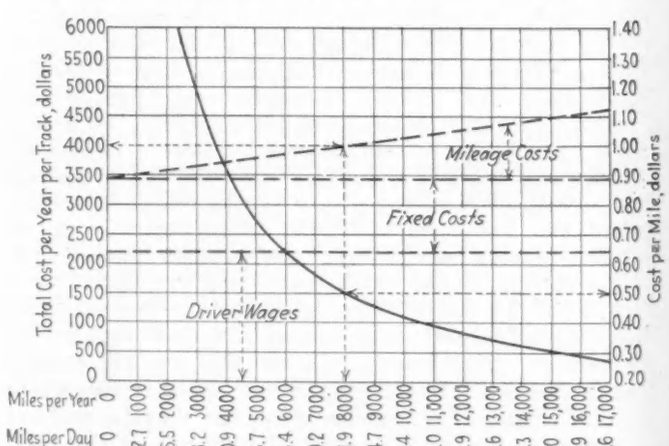


FIG. 1—OPERATING COST PER MILE

The Chart Shows Graphically the Variations in the Total Cost per Mile on Individual-Truck Operation with an Increase in Mileage

TABLE 2—DATA FOR FIG. 2 SHOWING VARIATION IN COST PER QUART WITH VARIATIONS IN LOAD AND MILEAGE

Miles per Year	*Cost per Truck* Per Year	Per Day	*Cost per Quart* Quantity Delivered per Day, Qt. 100	200	300	400	500
1,000	$3,510.80	$9.61	$0.0961	$0.0485	$0.0320	$0.0240	$0.0192
2,000	3,593.60	9.85	0.0985	0.0492	0.0328	0.0246	0.0197
3,000	3,656.40	10.00	0.1000	0.0500	0.0333	0.0250	0.0200
4,000	3,729.20	10.21	0.1021	0.0510	0.0340	0.0255	0.0204
5,000	3,802.00	10.41	0.1041	0.0520	0.0347	0.0260	0.0208
6,000	3,874.80	10.62	0.1062	0.0530	0.0359	0.0265	0.0212
7,000	3,947.60	10.80	0.1080	0.0540	0.0360	0.0270	0.0216
8,000	4,020.40	11.03	0.1103	0.0550	0.0368	0.0276	0.0220
9,000	4,093.20	11.21	0.1121	0.0560	0.0374	0.0280	0.0224
10,000	4,166.00	11.43	0.1143	0.0571	0.0381	0.0285	0.0228
11,000	4,238.80	11.60	0.1160	0.0580	0.0387	0.0290	0.0232
12,000	4,311.60	11.81	0.1181	0.0590	0.0393	0.0295	0.0236
13,000	4,384.40	12.01	0.1201	0.0600	0.0400	0.0300	0.0240
14,000	4,457.20	12.20	0.1220	0.0610	0.0407	0.0305	0.0244
15,000	4,530.00	12.40	0.1240	0.0620	0.0413	0.0310	0.0248
16,000	4,602.50	12.61	0.1261	0.0630	0.0420	0.0315	0.0252
17,000	4,675.60	12.80	0.1280	0.0640	0.0426	0.0320	0.0256

replacement and for parts gives $7,410, which, divided by 30, gives $247 per truck per year or, based on the average mileage of 10,000 miles per year, a cost of $0.0247 per mile.

Miscellaneous charges, item (5), include those for alcohol, in winter; skid chains and cross links; starting and lighting battery replacements; repairs to lamps, horn, and other accessories. An allowance of $50 per truck per year is made, or ½ cent per mile. The total cost per mile of operation is therefore as follows:

(1) Gasoline	$0.0200
(2) Oil	0.0050
(3) Tires	0.0160
(4) Repairs	0.0247
(5) Miscellaneous	0.0050
Total,	$0.0707

The total cost of operation is therefore the sum of the daily or fixed costs, $2.85 per day, and the variable or mileage cost, $0.0707 per mile.

But certain other factors must be given consideration before we can use the foregoing figures for analyzing delivery problems. This fleet of 30 vehicles includes four spare trucks and one service truck. The fact already has been developed that the annual fixed cost of owning one of these trucks is $1,051.36 per year. Multiplying this by the five extra trucks gives $5,256.80 per year that must be prorated over the 25 regular trucks to obtain a true cost-value. Dividing $5,256.80 by 25 gives $210.27 per truck per year as extra-ownership charges which, divided again by 365, is $0.57 per truck per day. This amount must be added to the daily fixed cost of the 25 regular-service trucks to get a true cost and to prorate this expense properly. The mileage run by these trucks can be ignored because it is assumed that they would be used only in place of a regular truck when necessary. The adjusted fixed-cost is therefore $2.85 + $0.57 = $3.42 per truck per day, or a total of $1,248.30 per year.

Some recognition must be given to the extra miles that will be run by the service truck over and above the necessary miles the regular trucks run in milk delivery-work. Assuming that this vehicle will run 7500 miles during the year, its cost per mile is $0.0707 × 7500 = $530.25. If each of the regular trucks runs 10,000 miles during the year, we must prorate $530.25 over 250,000 miles, which gives a rate of $0.00212 per mile. This amount added to the mileage cost of the regular trucks gives $0.07070 + $0.00212 = $0.07282 per truck per mile, the adjusted mileage-cost.

After consideration of both of the foregoing adjustments, we find that the actual cost of operation for the route trucks will be the fixed cost per truck per day, $3.42, and the variable cost $0.07282, per truck per mile.

No consideration has so far been given to driver costs. Driver compensation in the retail milk business is variable and complicated. It usually includes bonuses or commissions in addition to a fixed wage. To keep our analysis as simple as possible we will assume that this company pays its drivers a flat amount of $6 per day, or $2,190 per year. This gives a total fixed operating cost of $3,438.30 per year, or $9.42 per day, and a variable cost of $0.07282 per mile.

Variations in Mileage Cost

Table 1 was prepared from the foregoing data and is used as a basis for the preparation of Fig. 1, which shows graphically the variations in the total cost per mile on individual-truck operation with an increase in mileage.

Fig. 1 developed a fact which is of exceptional importance in making any analysis of truck operating-costs. Before any comparisons can be made, the basis of the figures must be the same. We often hear a fleet operator exclaim that he is not interested in mileage. Fig. 1 proves that, if he is to know his costs at all, a true knowledge of the number of miles which each vehicle has run is a fundamental requirement. It is not safe to compare the "cost per point," which is the standard method in the dairy industry, of a fleet in Chicago with a similar fleet in New York City, even assuming the same basis for collecting the data, or to assume the same fleet-operating efficiency, unless the mileage traveled by the individual vehicles is definitely known.

Referring to Fig. 1, let us compare two vehicles in the same fleet, one running 5000 miles during the year at a cost of $0.76 per mile, and another operated under exactly similar conditions but covering 15,000 miles in the same time at a cost of $0.302 per mile. A variation of more than 100 per cent exists in the cost per mile of

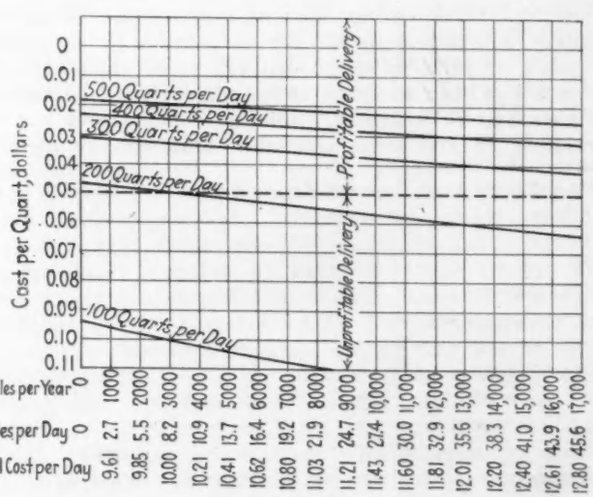


FIG. 2—COST PER QUART OF MILK DELIVERED

The Cost Is Given in Terms of Mileage and in Terms of Load. Profitable and Unprofitable Operation Can Be Determined in This Way, and the Chart Shows That the Costs Are Affected More Rapidly by a Decrease in Effective Load than They Are by an Increase in Daily Truck-Mileage

operating the two vehicles, and this is controlled by mileage only. This illustrates the primary importance of accurate mileage-records before any other form of cost analysis can even be attempted.

To apply this information to the actual delivery problem of our dairy company, let us assume further that it has an accurate record of the cost of its raw milk and of its plant costs of pasteurizing, bottling and the like in such detail that the complete cost per quart, or per point, on the loading platform ready to load into the delivery truck, is known. Let us assume this cost to be $0.15 per qt. and the retail price to the customer to be $0.20 per qt. This leaves a 5-cent margin to cover the delivery cost, including cost of the driver. It is assumed that the cost of route foremen and superintendants, and of salesmen other than drivers, will have been included in general plant overhead and will be a portion of the $0.15-per-qt. cost assumed. With this 5-cent margin let us apply our known truck-cost figures and build up a chart of cost figures based upon the cost per quart delivered, showing how they vary by quarts delivered and by miles traveled in accomplishing this delivery.

Table 2 is prepared by dividing the cost of operating one truck for 1 year, including the wages of the drivers, by 365 days to get a total cost per truck per day, and by taking truck loads in increments of 100 qt. up to and including 500 qt. per day and determining the cost per quart per mile. Table 2 is used as a basis for the preparation of Fig. 2.

Fig. 2 brings to light some very interesting facts. First, it is possible to determine at a glance whether any truck in daily operation upon any route is profitable or unprofitable provided the following two facts are known: (*a*) the number of miles the truck runs during the day and (*b*) the number of quarts delivered in that number of miles. Second, the costs are affected more rapidly by a decrease in effective load than they are by an increase in daily truck-mileage.

Proper Interpretation of the Data Presented

The facts and figures used in this paper are all assumed. The results may not check with individual experiences in operation. No attempt has been made to show the ideal, or an efficient, operation. Many milk dealers will object to the 5-cent margin in the cost of a quart of milk to cover delivery cost. I believe that 3 cents has been accepted as the mark not to be exceeded in this line of business. But if one analyzes his own problems in the same way that this specific case has been analyzed, possibly he will wish that the management would grant a 5-cent margin to cover actual costs. All the assumptions made are conservative, and duplicates of the conditions outlined can be found in many fleets in the retail milk-delivery service. As explained, the milk costs assumed have been chosen more to illustrate the point than to represent actual conditions.

An opportunity was presented recently to apply this method of analysis to the delivery problems of an Eastern dairy. The company was operating 12 wholesale and 32 retail routes. Of the 32 retail routes, 19 were unprofitable for 7 months per year. These facts were hidden, however, in the profitable operation as a whole brought about by exceptional profits in the wholesale routes only. These retail routes were unprofitable merely because they were carrying loads that were too small. The company had the choice of two methods of correcting the difficulty; first, to build up the routes to a profitable-load point, or, second, if this was impossible, to close out the ones which could not be so increased. The development of these individual-route data, and by this means finding the offending routes, would not have been possible except by the method used here. Obtaining information for such a purpose may seem complicated, and it can very easily become so if a proper analysis of the method of procedure is not made beforehand.

All items of fixed cost can be determined for a year at one time. Adjustments of this record would have to be made only when there was any increase or decrease of the number of trucks owned by the company, and adjustments would have to be made only when such changes occurred. All items of mileage cost need to be recorded daily, per truck. A single card for each truck can be used to show the number of gallons of gasoline and quarts of oil used, the mileage covered, the number of quarts delivered and those returned, tires changed and the like. This daily information can be transferred to a monthly truck log-sheet summarizing the work of the month. Twelve of these sheets would form the annual file record of the individual-truck performance.

Keeping cost records is a simple matter when all cost factors can be recognized and classified. It is carelessness in the consideration of these factors that leads to difficulty. This is particularly true in the overhead or burden items. In closing, I commend to attention an article by Alvan C. Macauley, President of the Packard Motor Car Co., entitled, You Can't Compete with Careless Overhead[2]. The truck delivery-fleet of any company is very likely to be the most prolific source of leaks of this character.

[2] See *Magazine of Business*, September, 1927, p. 267.

The Army System of Maintenance of Motor Transportation

By First-Lieut. Walter C. Thee, U.S.A.[1]

Transportation Meeting Paper *Illustrated with* Charts and Photographs

A MORE appropriate title for this paper would be The Application of the Laws or Fundamental Principles of Industrial Organization and Management to the Maintenance of Motor Transportation. This title furnishes the explanation how and why the Army maintains its own equipment, operated in all parts of the world, with soldier labor. It also helps to explain how the Army has maintained its own equipment at a cost much lower than have any other operators of motor transportation.

The Army, with its operating centers widely dispersed and its maintenance or repair centers closely combined, is admirably situated to recommend to commercial operators of motor transportation its system of maintenance. The influence that the laws of management have had in the advancement of the maintenance of motor transportation from the vocational to the professional plane may be exemplified by citing a few instances of the direct adaptation of the laws or fundamental principles of management to the Quartermaster Corps Motor Transport, Reconstruction Park, Camp Holabird, Baltimore.

The author discusses the great shortage of skilled mechanics who are required for the maintenance of the ever increasing number of motor-vehicles, and the difficulty of getting satisfactory service. He also explains how the Army is solving the problem of securing a sufficient number of men to do satisfactory work in maintaining the motor-transportation equipment operated by the Army. In accordance with the laws of management, the three accepted ways of getting satisfactory work done by unskilled labor are, division of labor, leadership, and incentive reward. Other accepted ways are, authority with responsibility, transfer of skill, and task work. The Army shops at Camp Holabird apply these laws and fundamental principles by dividing the shops into departments and subdividing the departments. The labor of maintaining and reconditioning motor-transportation equipment is divided so that to each worker is assigned either one or a very few manual or mental operations. This one factor in management tends greatly to improve the quality and to increase the quantity of the output of unskilled labor. The term "skilled labor" or "expert mechanic" is minutely defined by the author.

Another important factor that the shops at Camp Holabird demonstrate in a very clear way is the assigning of a definite task to each department or group of workers by the use of production boards which show the quantity required to be produced in a given period. These departmental production boards not only set a definite task but create incentive in the workers by giving them credit for the work done. When the men are given credit for the work done, through the posting by its foreman of the number of units completed by each group of workers, they have an incentive to work fast and take an interest in the organization.

Means of increasing production are described and illustrated with charts. The statement is made that during the last year considerable study has been devoted to the subject of the unit-replacement system for making repairs to motor-transport vehicles.

THE Army system of maintaining motor-transportation equipment is simply an application of the fundamental principles of industrial organization and management to a particular problem. The Army is thus able to maintain its equipment, which is operated in all parts of the world, with soldier labor, at a cost much less than that of any other large operator of similar equipment.

With its operating centers widely separated and its maintenance or repair centers closely combined, the Army is admirably situated to recommend its system of maintenance to commercial operators of motor-transportation equipment. The influence that the laws of management have had in advancing the maintenance of motor-transportation vehicles from the vocational to the professional plane may be exemplified by a few instances of the direct adaptation of these fundamental principles of management by the Quartermaster Corps Motor Transport, Reconstruction Park, Camp Holabird, Baltimore.

A great shortage of skilled mechanics exists in the automotive industry and the need of them is continually becoming greater because of the increasing number of motor-vehicles in operation. The problem of getting satisfactory service on motor-vehicles is becoming clearly recognized among automobile manufacturers. In the Army, this problem is being solved by the training of mechanics in sufficient numbers to maintain the motor-transportation equipment operated by it.

In accordance with the laws of management, the three accepted ways for getting satisfactory work done by unskilled labor are, division of labor, leadership, and incentive reward. Other accepted ways are, authority with responsibility, transfer of skill, and task work. The Army shops at Camp Holabird apply these fundamental principles by dividing the shops into departments and subdividing the departments. Organizing the shops in this way divides the labor of maintaining and reconditioning motor-vehicles so that only one or very few manual or mental operations are assigned to each worker. This fact tends greatly to improve the quality and to increase the quantity of the output of unskilled labor.

An important feature that is demonstrated in a very clear way at Camp Holabird is the use of production boards, which show what is required to be produced by each department or group of workers during a given period. These production boards not only set a definite

[1] M.S.A.E.—Property and maintenance officer, Army motor service, Quartermaster Corps, First Corps Area, Boston.

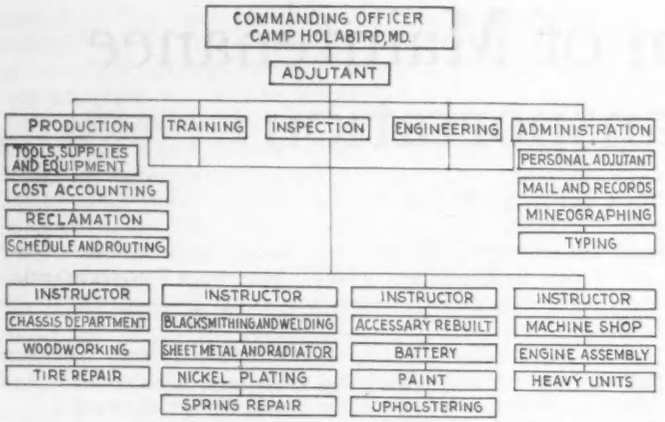


FIG. 1—ORGANIZATION CHART OF THE SHOPS AT CAMP HOLABIRD

Each of the Allied Trades Departments Has a Foreman and an Inspector Who, in Addition to Their Regular Duties, Are Assistant Instructors. The Instructors Are also General Foremen. Production Is Supervised by the Works Manager. There Are also a Superintendent of Training, a Superintendent of Inspection, a Superintendent of Engineering, and an Administration Executive. Instruction and Production Are Thoroughly Coordinated and Neither Suffers from Lack of Fixed Responsibility. So far as the Student Is Concerned, Instruction Is Primary and Production Is Secondary

task but create an incentive by giving the workers credit for the work done. So long as the men see that they are given credit for their work, they have an incentive to work fast, and take an interest in the organization.

ARMY ORGANIZATION FOR MAINTENANCE WORK

To explain the Army system of maintenance of motor-vehicles, it is necessary only to explain the organization chart, shown in Fig. 1, which is based upon the functional idea in management. It represents graphically the plan for dividing the responsibility in the management of the plant.

The five factors that constitute this problem at Camp Holabird are: (*a*) production, (*b*) training, (*c*) inspection, (*d*) engineering, and (*e*) administration. All these are controlled by separate groups of individuals at whose head is the commanding officer, whose adjutant is the general manager.

The first factor comprises the manufacturing plant, at the head of which is the works manager, and includes scheduling and routing, supplies, the maintenance of buildings, and the entire process of manufacturing or repairing and shipping the product.

The second factor includes the training of the personnel. This must be closely coordinated with production so that the fundamental principles taught in the classroom can be applied to units listed in the production schedule. It is important that this coordination be developed to its highest degree. By giving the student actual production work to do, whenever possible, not only is a considerable saving made in the cost of instruction, but the interest of the student is much greater when performing operations on parts that he can recognize than it is when he is working on a set exercise, even though the nature of the work may be the same in both cases.

The third factor includes inspection of the products. It comprises a separate group of individuals who make sure that the quality of the work complies with definite specifications. When inspections are made along the line, the inspectors of the various departments make the necessary corrections in an instructive manner.

FIG. 2—ENLISTED MAN REBORING MAIN CRANKSHAFT-BEARINGS WITH A SINGLE-POINTED BORING-BAR

By Organizing the Shops into Departments, the Work Is Divided so that One or only a Very Few Manual or Mental Operations Can Be Assigned to Each Worker. This Tends to Improve the Quality Greatly and To Increase the Quantity of the Output

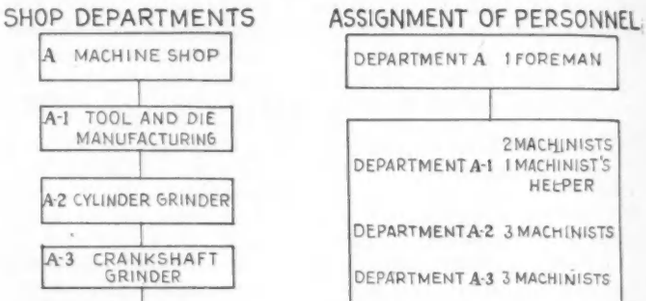


FIG. 3—ORGANIZATION CHART AND ASSIGNMENT OF PERSONNEL FOR MACHINE-SHOP

The Departments Are Subdivided so that Each Worker Performs One or only a Very Few Operations for Which He Is Particularly Adapted

The engineering section, the fourth factor, determines, from experiments conducted by it and from the data thus secured, an approved list of providers of materials. It assists in the preparing of specifications for vehicles, parts, materials, lubricants, fuels, and the like. It is charged with the inspection of materials purchased as regards quality, serviceability, and compliance with the specifications. This section also redesigns and constructs initial and special equipment, in addition to doing all development work, vehicle testing, metallurgical work, and the testing of fuels and lubricants. It is charged with the preparation of a progressive program for the designing and constructing of vehicles that are peculiar to the military service, and, after so designing and constructing them, of selling them for use in commercial work, so that a reservoir of this type of vehicle will be provided upon which the Country can depend in time of emergency.

The administrative section, the fifth factor, is charged with all office routine, correspondence, personnel work,

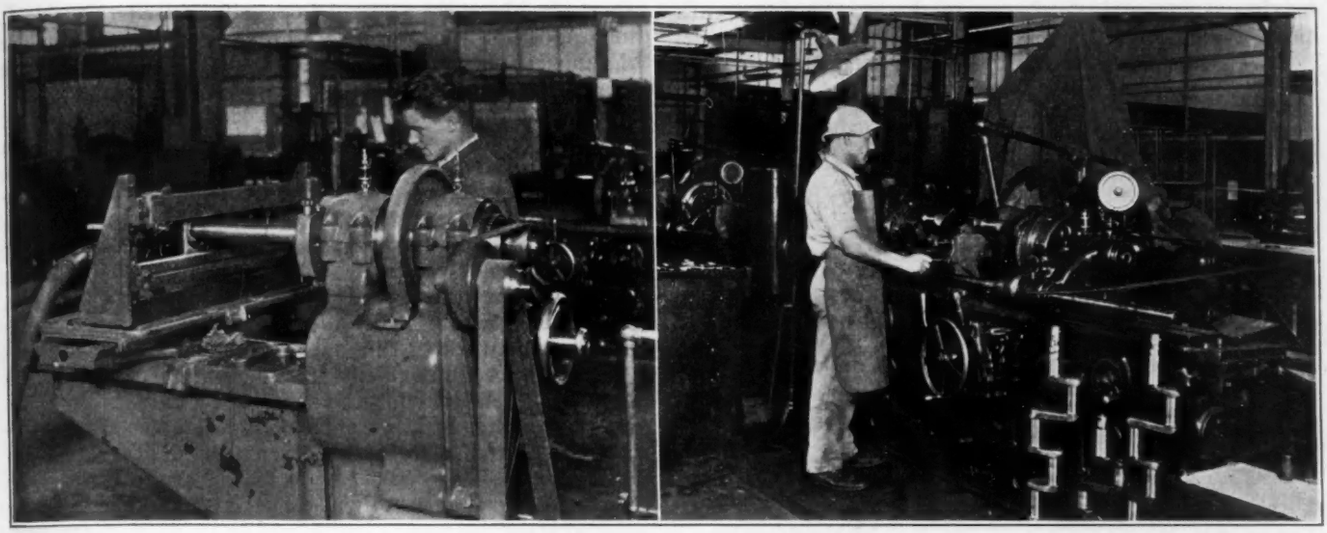


FIG. 4—ENLISTED MEN REGRINDING CYLINDER-BLOCKS AND CRANKSHAFTS

After a Man Has Become Familiar with the Manual or Mental Operations Required, He Produces the Same Quality and Quantity of Output as a Skilled Mechanic. Men Assigned to Cylinder Grinding Can Be Taught Very Quickly To Regrind Cylinders within 0.0001 In.

such as attendance, pay and morale of the men, mail, records, and the like. It executes or carries out the objects for which the enterprise is organized, initiates the work to be performed, sees that the personnel is fitted for the work, and, in general, takes care of the everyday routine necessary to ensure that men, materials, and equipment are functioning properly.

FUNCTIONAL ORGANIZATION OF PRODUCTION DEPARTMENT

Although each of the five departments is of prime importance, the first particularly concerns us in this discussion. To continue with the mission of the production department, attention is again invited to the diagram, Fig. 1, representing the division of duties and responsibilities as generally arranged for establishments such as we are considering. These shops rebuild about 12,000 units per month. A unit is a part or assembly, such as a carbureter, magneto, vacuum tank, engine, transmission, clutch, front or rear axle, steering-gear, spring, body, seat, cushion, top, or any unit or part that can be replaced in the field by an unskilled mechanic with ordinary hand-tools in less than 8 hr. To use soldiers who are unskilled mechanics, or who are not so well rounded as an expert mechanic, in rebuilding these units, it is necessary to divide the work so that all the qualities of a well-rounded man shall not be required. By organizing the shops into the departments listed below, the work is divided so that one, or a very few, manual or mental operations can be assigned to a worker. This tends to improve greatly the quality and to increase the quantity of the output. The names of the divisions or departments of the shops have been chosen with great care so that they shall be brief and at the same time possess the

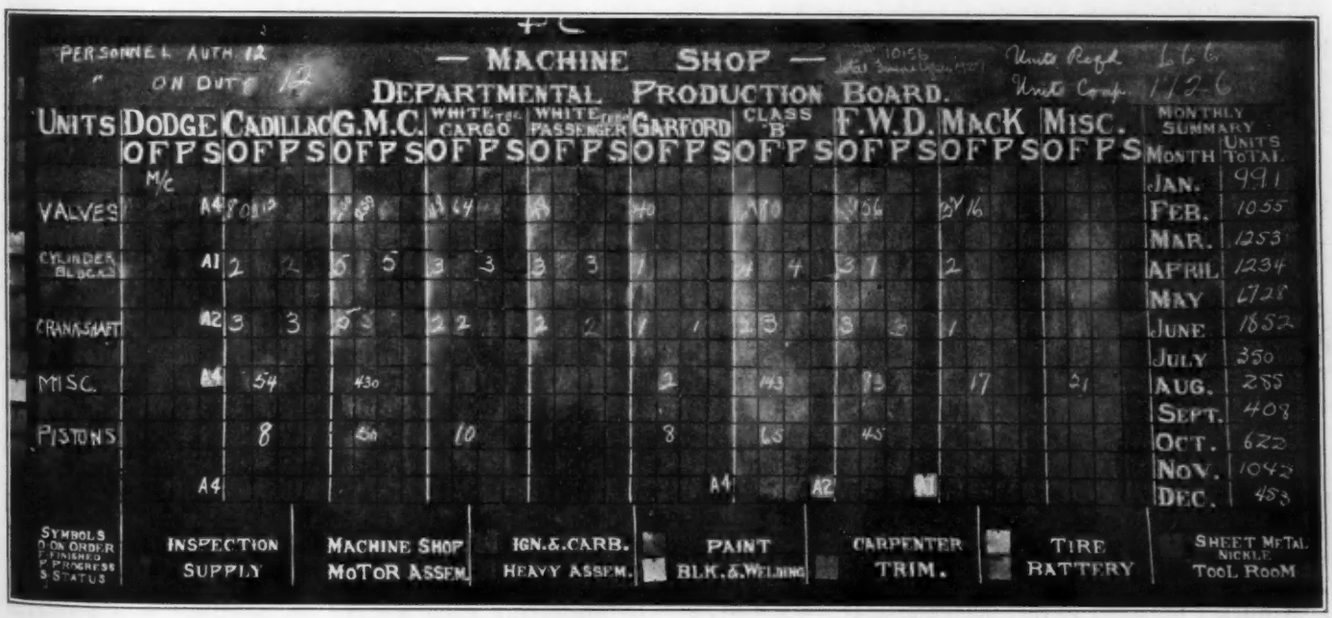


FIG. 5—PRODUCTION BOARD LOCATED IN THE MACHINE-SHOP

This Board Shows the Production Schedule and the Status of All Work in the Department

maximum suggestive value as to their scope and limitations.

Divisions or Departments

(1) Machine-shop, where cylinder-blocks, crankshafts, wristpins, and the like are reground, and bearings and miscellaneous parts are manufactured and fitted
(2) Engine-assembling department, where crankcases, pistons, connecting-rods, cylinders and accessories are assembled
(3) Heavy-units department, where fitted parts of transmissions, clutches, front and rear axles, steering-gears, universal-joints, propeller-shafts and brakes are assembled
(4) Accessory-units department, where carbureters, ignition units, electric generators, starting-motors, fans, speedometers, pumps, gages, and the like are rebuilt or repaired
(5) Battery department, where old batteries are dismantled and the serviceable parts are reclaimed. This department also manufactures post straps and top connectors, assembles positive and negative groups, and builds, tests and charges batteries
(6) Trimming and upholstering department, where tops, tarpaulins, side curtains, seat covers, cushions, visors, carpets, tire covers, flag cases, and the like are rebuilt or repaired
(7) Painting department, where vehicles and units are painted with either nitrocellulose compounds or oil paints and varnishes
(8) Blacksmithing and welding department, where frames and other metal parts are rebuilt or repaired
(9) Sheet-metal and radiator department, where fenders, heaters, gasoline-supply lines, gas-tanks, lamps, hoods, mufflers, metal bodies, radiator cores and shells are manufactured, rebuilt or repaired
(10) Nickel-plating department, where all nickeled parts are cleaned and replated
(11) Spring-repairing department, where all springs are manufactured, repaired or reset
(12) Tire-repairing department, where pneumatic tires are mounted, solid tires are pressed on or removed from the wheels, and tubes and casings are repaired
(13) Woodworking department, where bodies, seat boxes, dashboards, bumper blocks, sills, running-boards, floor-boards, seat frames, battery boxes, wheels, and the like, are manufactured or repaired
(14) Chassis department, where the various units that have been manufactured, rebuilt or repaired in other departments are assembled

Each of these departments is further subdivided so that each worker is assigned to an operation that he is particularly adapted to perform. This allows the worker to concentrate his efforts and rapidly to improve both the quality and the quantity of his output. One of the operations is shown in Fig. 2.

Machine-Shop Organization and Operation

The organization of the machine-shop may be used as an example, in which the various duties are subdivided as shown in Fig. 3. The various departments and divisions in the shop have been given a letter symbol, the purpose of which is to aid in designating the different departments for administrative purposes.

A worker assigned to this department is trained to operate only one machine, such as a grinder for regrinding cylinders or crankshafts, as in Fig. 4. In a remarkably short time he can be taught to regrind cylinders to 0.0001 in. After he has become familiar with the manual or the mental operations required, he will produce the same quality and quantity of output as a skilled mechanic.

To obtain a broader and clearer idea of the mission and accomplishments of this organization, the work in the various departments is subdivided as shown in Fig. 5. This figure includes all the data that are shown on the production boards, which are installed in every department of the shops and show the production schedule for the month and the status of all work.

Fig. 6 shows the organization chart of the heavy-units department, while Fig. 7 illustrates the method of subdividing the work in this department and shows its mission and accomplishments in detail, as well as the production schedule for the month and the status of all the work. Fig. 8 shows enlisted men engaged in assembling the fitted parts of a rear axle and of a steering-column.

An enlisted man who is assigned to this department to rebuild steering-gears can become so proficient in a very short time that the quality of his work will be better and the quantity greater than that of skilled mechanics who have not specialized in this particular line.

Simplification or Specialization Reduces Cost

Fig. 9 illustrates how all the work that requires specialization of the job and individual workers is divided. Having a worker concentrate upon the repairing of a single unit or a few units tends to increase the dexterity of the worker, to improve the quality of the output, and to lower its cost. It also saves time that is commonly lost in changing men from one kind of work to another and in their becoming familiar with the special features involved. Fig. 10 shows enlisted men engaged on various assembling, inspection, and testing operations, and Fig. 11 shows one rebuilding carbureters.

Work Assigned According to Natural Abilities

I do not mean to imply that any recruit or soldier assigned to a shop can be detailed to rebuild steering-gears or to regrind cylinders and can produce satisfactory results. Every worker, as soon as he reports to the shop superintendent for duty, must be studied, as the highest individual productivity is possible only when a worker is given the highest class of work for which his natural abilities fit him. A man may be better qualified to become a clerk or a timekeeper than a woodworker or upholsterer, because of a natural inclination or aptitude for such work; or a man may prefer to work in the blacksmithing department or the powerplant because, as a civilian, he has worked in a blacksmith shop or has stoked a boiler. Most of the men now entering the service are under 21 years of age and have not completed an apprenticeship or learned any trade thoroughly. A large number of the men come directly from the farm or the coal fields. Men of the latter class especially prove to be very good mechanics and, under functional shop supervision, learn to perform unit operations in a very short time.

Consolidation and Cooperation Necessary

A question that always is asked during a discussion of this subject is whether it would be profitable for an operator of a fleet of motor-trucks, or the manager of a service-station, to build up so elaborate an organization. In answering such a question, practical considerations must govern. It certainly would not be profitable to install equipment, such as that for charging storage bat-

teries, if the saving from the number of batteries charged would not pay for the equipment and the cost of operation. The same is true of any other department. Only departments whose existence is warranted by the large quantity of work that can be classified as above should be retained or installed.

A very small service station or shop department cannot possibly have the proper equipment for performing the best work in a large number of operations. Many service stations should not exist, at least insofar as the repairing of defective units is concerned, since they do not have enough work of one kind to allow them to enjoy the benefits of an ideal organization. For example, they should not attempt to rebuild ignition units and storage batteries, to regrind cylinders, to rebuild tops, bodies, and the like, but, instead, should send them to an organization that is properly equipped for such work. Large organizations could be built up and operated on a cooperative plan; that is, operators and dealers could cooperate with journeymen in the various trades connected with the maintenance of motor-transportation equipment, so that they can derive the benefits of large-scale production.

Mass Production Required to Decrease Cost

The laws of mass production developed by L. P. Alford, vice-president of the Management Engineering Corporation, are:

(1) Large-scale production tends to increase operating efficiency and competitive power
(2) In large-scale production, the unit-time of production tends to approach the actual operating-time as a limit

A remarkable factor in the development of manufacturing is the increase in the size of factories and industrial enterprises. The advantages of large size are reduced cost of production, relatively smaller reserves to meet contingencies, and a stronger position in competition. The first of these is due to the greater opportunity to apply fully the laws of specialization; the second, to the greater fluidity of stores of materials, tools and stocks

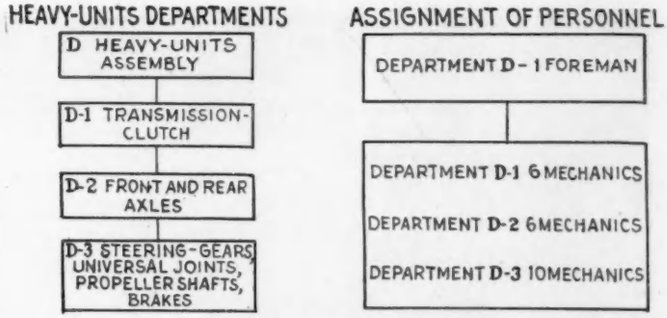


FIG. 6—ORGANIZATION AND ASSIGNMENT OF PERSONNEL OF THE HEAVY-UNITS DEPARTMENT
Every Other Department Is Organized in a Similar Way

of goods; the third, to enlarged prestige, influence and ability of the personnel.

Assignment of Tasks and Recognition of Work

Two laws or principles of manufacturing management are:

(1) The average worker accomplishes most when he is assigned a definite quantity of work to be done in a given time.—Taylor
(2) Recognition of an accomplished task influences a workman to maintain his maximum output and take an interest in the organization

These laws, or fundamental principles, are applied to the type of organization referred to in this paper by the use of the departmental production boards, one of which is located in each department of the shop. On it is posted the quantity of work that each department or group of workers is required to produce during the month. An average worker will be more ambitious and take a greater interest in the work if he is assigned a definite amount of work to be completed in a given time and receives credit for the work that he performs. In addition to showing the workers the amount of work that is required of them and crediting them with the work done, the production boards control, to a great ex-

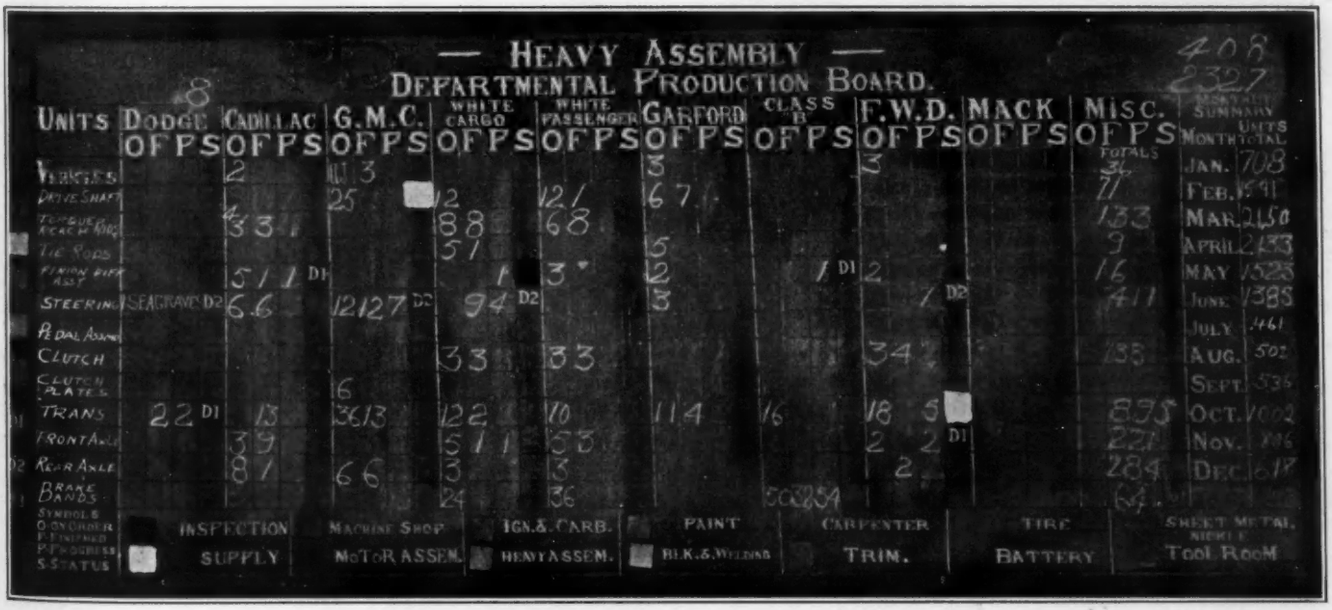


FIG. 7—PRODUCTION BOARD IN THE HEAVY-UNITS DEPARTMENT
This Shows the Accomplishments of the Department in Detail, as Well as the Production Schedule for the Month and the Status of All Work. Square Tags of Different Color Are Warning Signals

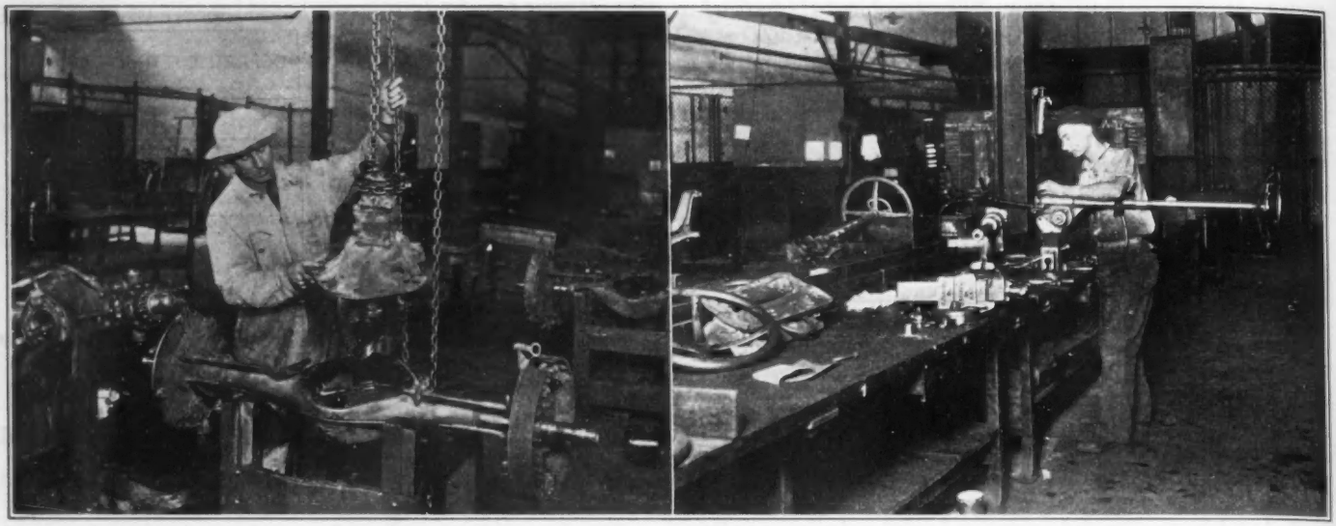


FIG. 8—ENLISTED MEN ASSEMBLING THE FITTED PARTS OF A REAR AXLE AND A STEERING-COLUMN

Defective Rear-Axle Units or Assemblies Can Be Repaired Satisfactorily Only When Qualified Personnel and Adequate Facilities Are Available. A Student Can Be Put on a Productive Basis within 3 Days After Having Been Assigned to the Steering-Gear

tent, through the guidance of the scheduling and routing department, the flow of material or units, and provide a quick signal for a shortage of supplies or any delay in production. Upon these boards is posted the monthly production program, which is always prepared at least 30 days in advance. Therefore, as stated, the production boards not only supply information but show the exact amount of work going on in the shop at any period; and they have an extensive application as a means of bringing exceptions quickly and forcefully to the attention of the management. If, for example, 48 pistons were on order, as shown by the production schedule of the engine-assembling department, and the status of the order were that they were being delayed because of lack of supplies, a red tag, the symbol for shortage of supplies, is hung up in a place provided for it and the officer in charge of supplies must devote his undivided attention to filling the requisition calling for the necessary supplies. If the order were held up because of inspection, a yellow tag would be used; if on account of the machine-shop, a blue tag would be used. If the group of workers assigned to this department were holding up the order, a tag marked D-3 would be hung up in the column marked *S*, which is the symbol for status.

GOOD LEADERSHIP OF FIRST IMPORTANCE

One of the most important factors in securing satisfactory work at a reasonable cost with unskilled labor is leadership. The following is the law of leadership, as developed by L. P. Alford:

Wise leadership is more essential to successful op-

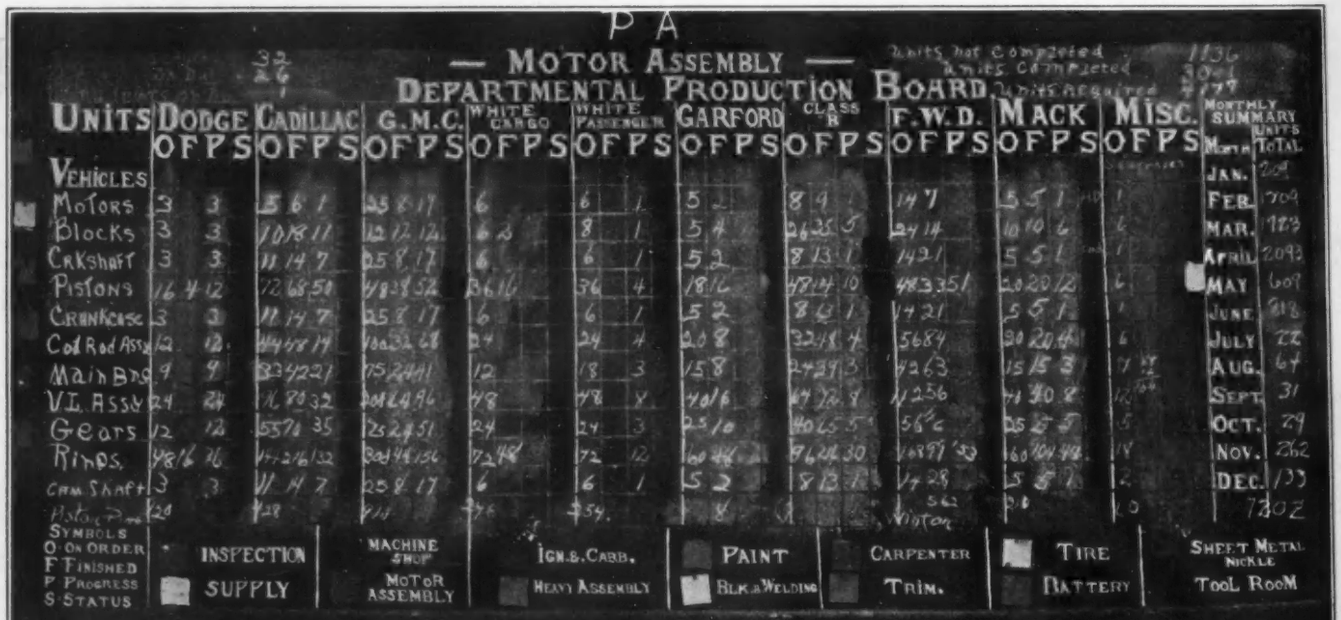


FIG. 9—PRODUCTION BOARD OF THE ENGINE-ASSEMBLING DEPARTMENT

This Board Shows Clearly How Work Is Divided That Requires Specialization of the Job and of the Individual Workers. A Hold-Up in Production Due to Lack of Supplies Is Signalized by a Red Tag; to Inspection, by a Yellow Tag; and to the Machine-Shop, by a Blue Tag

eration than extensive organization or perfect equipment.

Mr. Alford has remarked[2] that this law has long been recognized in military affairs, having been succinctly stated by one of Napoleon's historians as

> Wise direction is of more avail than overwhelming numbers; sound strategy than the most perfect armament.

Mr. Alford continues:

> These facts, so plainly recognized in military history, have their exact counterpart in manufacturing. The factory and office invariably reflect the manager. His policy and direction are the deciding factors for success or failure in operation.
>
> The application of this law replaces the autocratic methods of driving and forcing by the democratic methods of teaching and training.

The best and most successful managers are the leaders, not the drivers, of men. The quiet and methodical manager naturally creates an atmosphere of loyalty and discipline among his subordinates, who obey his orders with alacrity and good faith. Hence, good results flow naturally from their united efforts.

[2] See *Mechanical Engineering*, April, 1927, p. 30.

Advantages of Unit-Replacement System

The system of maintenance of motor-transportation equipment that has just been described naturally lends itself to the unit-replacement system of making repairs at stations, or by organizations that have not the qualified personnel or the proper facilities for repairing defective units. The unit-replacement system is self-explanatory. It has been in use for many years in making repairs to commercial vehicles and is used by the Army exclusively in the various corps areas throughout the United States.

Fig. 10—Enlisted Men Inspecting and Testing Parts and Assembling an Engine

(Upper Left) Inspecting Multiple-Disc Clutches. (Upper Right) Testing Magnetos. (Lower Left) Testing Carbureters. (Lower Right) Assembling an Engine. Every Unit Rebuilt or Repaired Must Comply with Definite Specifications before It Is Available for Issue under the Unit-Replacement System. Many Men in the Army Transport Service Have Been Professional Soldiers for 20 to 30 Years and Were Formerly Electrician Sergeants or Specialists in Other Branches. The Highest Individual Productivity Is Possible only When Each Worker Is Given the Highest Class of Work for Which His Natural Ability Fits Him

The idea was put into effect more forcefully during the war than at any time before or since.

The advantages of the system are:

(1) It utilizes the economic value of an old vehicle
(2) It allows an operating center to make needed repairs with greater economy and less loss of time to vehicular operations
(3) Skilled or expert mechanics are not required
(4) The maintenance cost is decreased
(5) The stock to be carried on hand is decreased

A vehicle has a certain cost and, when it is standing idle, the economic loss is great. If a vehicle costs $5,000, to get a return on the money invested, the vehicle must

work. If it is laid up for extensive repairs, $5,000 is, in effect, idle and not only has no earning power but is a dead loss.

The operation of transportation units, so far as the Army is concerned, is not different from operation of similar units in any commercial manufacturing plant. Under the present budget-system for supplying funds for the Army, it is necessary that costs be kept at the minimum; therefore, the unit-replacement system is used. This consists, ideally speaking, of a particular operating center's having on hand a certain percentage of repaired or rebuilt units that can be applied to replace worn units in the vehicles that are being operated by that particular center. When a vehicle is not operating economically, it is run into the shop so that the units that are worn can be replaced. The replacement can be made in a short time and the vehicle released for further earning without a long delay and economic loss.

As soon as the units have been exchanged, that is, the old one taken out and the new one installed, the old one is sent to a central repair-plant. No operating center, as such, should maintain a repair plant. No particular operating center can have authority over a repair plant. This is obvious, as the officer in charge of an operating center would, naturally, have the entire facilities of the repair plant working for his operating center. The repair facilities, therefore, must be distinct and separate, and must serve a large field, the larger the better.

A unit, having been removed from the chassis, is forwarded to an independent repair-center where it is immediately repaired; if not repaired, another unit, or a similar chassis or vehicle, is immediately forwarded and the old one is placed in the regular production schedule of the repair center. When the repairs have been completed, it is placed in stock, to meet the demands of the operating centers for economic transportation.

Operating centers may obtain and maintain, if desired, a reserve stock of unit assemblies and subassemblies in accordance with the following:

(1) Separate requisitions are prepared and forwarded through the regular channels
(2) In each case, appropriate notations are made on the requisition to show that the additional units or subassemblies are for reserve stock
(3) The number of units called for in any case does not exceed 10 per cent of the particular make or type of vehicle actually being operated locally, including the number of such units and subassemblies on hand, en route or on requisition
(4) Requisitions show the numbers of particular types of vehicle on hand authorized for operation and the quantity of units and subassemblies on hand or on requisition, if any
(5) Reconstruction and overhaul parks are authorized to issue, on approved requisition, units and subassemblies for reserve stocks at operating centers, provided these can be furnished without undue interference with or interruption of the supply of units and subassemblies requisitioned for immediate use; otherwise, the requisitioner will be advised that the items are considered cancelled
(6) Immediately upon the withdrawal of a unit or a subassembly from the local reserve stock for the purpose of replacing a unit that has become unserviceable, action is taken to return the unserviceable unit to the reconstruction or overhaul park

An exception that must be managed carefully when using the unit-replacement system is the stripping of units before they are sent to the large repair units from the field. Operating officers should be held strictly responsible for seeing that the units repaired and sent from the supply point are used as a whole and not as a source of supplies for ordinary repairs; that is, no operating officer should be allowed to tear down any unit to obtain parts for the repair of another unit at the operating center.

An Efficient Inspection System Is Necessary

A danger that must always be apprehended in this system in the field is that units other than the principal ones may wear out at the same time that the principal units wear out; it is necessary, therefore, to have a minute and efficient inspection system that will cover the entire vehicle so thoroughly that other units which may give way in a short time will be detected. To make the unit-replacement system work efficiently and economically, care must be taken that units that are inspected at the same time can be replaced, if necessary, at the same time.

System of Making Unit Repairs

The system of unit repairs in the Camp Holabird shops is as follows:

(1) Units are accepted by the shop on a request for repairs and are held by the schedule and routing officer in the reclamation department until the shop is ready to start work. Units are accepted by the shop after having been passed upon by an inspector, who determines (*a*) that unserviceability apparently was due to reasonable wear and tear, (*b*) that units or vehicles are complete, and (*c*) that units or vehicles are economically repairable
(2) The schedule and routing officer receipts for the units or vehicles on the duplicate copy of the request for repairs, which serves as a memorandum receipt to the property officer
(3) When a unit is started through the shop for repairs, the schedule and routing department accomplishes a shop order covering the unit; and under no circumstances is work started on a unit or vehicle unless a shop order accompanies it
(4) When a unit is found by the inspection branch to be not economically repairable as a unit, it is routed to the reclamation department and a credit requisition is furnished to the schedule and routing department to close the work order. A survey is then prepared by the schedule and routing officer to cover the unit. When the work order is closed by a credit requisition from the reclamation department covering the unit, a copy of the cancelled work-order is furnished to the property officer, who notes it upon the face of his retained copy of the request for repairs
(5) Upon completion of work on any unit, and after the unit has been passed by the inspection branch, the schedule and routing department sends it to the property officer, taking a receipt for it upon a move order. When this receipt is obtained, it is attached to the shop order and, with all other papers pertaining to the job, is forwarded to the cost department for final disposition
(6) Department foremen and schedule and routing clerks are directed to take special care that the file on each job is complete before sending it to the cost department to be closed; that is, that shop orders or debits, credit requisitions, time tickets and move orders are all in order
(7) When a unit requires work in more than one department, the work order and move order go with the job and are routed to the next department
(8) Subshop orders are used when work in another

department is required before the first department can finish its part of the work

(9) No attempt is made to repair parts taken from a unit for the purpose of replacing the job. New parts are drawn and the old parts are routed on the credit requisition to reclamation, from which they are sent to the shop on a new shop order to be repaired and returned to stock.

The salvaging and reclaiming of all unserviceable parts and assemblies sent in by the field is a function of the reclamation department. This is the most important department in the shop and is accomplishing something that is seldom carried out, I believe, so thoroughly and successfully in civil operations. This department furnishes other departments, such as the machine-shop, the heavy-units department, the engine-assembly accessory-units department, and so on, with the units and assemblies called for on the production schedules. All material that is not economically repairable is disposed of as scrap metal.

Conclusions

Compliance with the latest laws and fundamental principles of industrial organization and management requires that there shall not be a shortage of qualified mechanics, and that it shall be possible to secure satisfactory work at a reasonable cost with unskilled labor. The demand for skilled mechanics who are qualified to repair motor-vehicles is increasing rapidly and the supply today is so low that energetic steps must be taken to give operators satisfactory service. The number of service stations that are giving satisfactory service because they are properly equipped and well managed is limited, and even in such stations the cost of the service is often prohibitive. On this account, service stations with elaborate equipment and an expensive system, all of which increases the overhead expense, cannot make a reasonable profit or have satisfied customers. It is necessary to operate such plants at full capacity to give satisfactory service at a reasonable price. This will enable an enterprise to operate at a profit and have satisfied customers who will return for more service instead of trying to economize by making their own repairs or going to a small garage. By using the functional idea of management, it is possible, in a comparatively short time, to train foremen and mechanics who can perform the functions demanded of them.

The all-round automobile mechanic, or so-called jack-of-all-trades, cannot do all things well and should not be expected to do so. In his stead should come management by a system of divided and properly distributed responsibility.

I do not intend to leave the impression that production and instruction are identical. This would give a worker a loophole for saying that instruction is being subordinated to production. I desire to emphasize, however, that production and instruction are thoroughly coordinated and that neither suffers. So far as the student is concerned, instruction is primary; production is secondary.

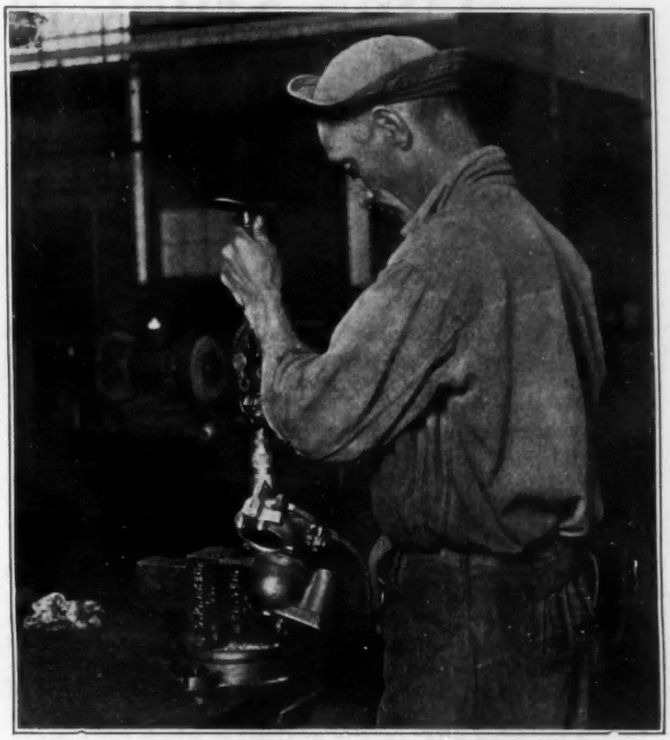


Fig. 11—Enlisted Man Rebuilding Carbureters

Under the functionalized system of maintenance, a general foreman is in charge of all departments that are more or less related. In addition to his regular duties, he is an instructor in the subjects pertaining to his department. Each department has a foreman and an inspector who, in addition to their regular duties, are instructors in the subjects pertaining to their departments. The organization also includes a works manager, a superintendent of training, a superintendent of inspection, and an administrative executive.

The basic soundness of the unit-replacement system is well known and has been proved by the test of time. The Army is admirably situated to recommend this system because its operating centers are widely dispersed, and its maintenance or repair centers are closely combined and are able to cover the entire territory of operation within economical freight-shipping distance.

Progress in Congestion

I HAVE long believed that traffic density has as definite an effect psychologically upon motorists in crowded districts as that force which causes a panic when hundreds of people try to reach a certain exit in a crowded hall or theater following an alarm of fire.

An unbroken line of cars will be winding slowly but steadily in or out of the city on one of the popular thoroughfares during a rush hour, when all of a sudden a driver will shoot his car out of line, risking life and limb, not only of himself, but of those with him, and of passengers in other cars. Then he darts into the line again, perhaps only two or three car lengths ahead of where he was before. Practically no time has been gained by the maneuver, and the same amount of space could have been gained by the closing up of the whole line to fill in the gap. It is just a spurt as a result of over-tensed nerves. The driver feels that when he is in a line of automobiles he is not getting anywhere, when, in reality, he may be going only a little more slowly than the rate that is called for in the traffic regulations.—J. H. Hulett, in *Motor Travel.*

Time-Study in Its Relation to Labor Budget

Discussion of E. J. Frounfelker's Production Meeting Paper[1]

IN the early days of time-study work, the labor cost was obtained after production had started and after the tools and machinery had been made; but use of the control budget, by which all controllable expenses such as non-productive supplies, non-productive labor and other miscellaneous expenses for a given production were predetermined, constituted a progressive step which led to the establishment of time-study departments. The control budget of the past did not include productive-labor costs.

The method used by the company represented by the author for the predetermination of labor costs is outlined. After the working drawings are approved, a committee of the manufacturing department, on which is a representative of the time-study department, discusses tools, equipment, methods and labor costs, and makes comparisons with other models. The labor cost is budgeted after careful analysis in which tools, equipment, comparison with other models, and itemized time-elements are considered in the sequence in which they are to be performed. Analysis of the different time-elements is presented by the author, and a summary is made of the advantages of the method described and the results obtained.

Points raised in the discussion and replied to by the author of the paper relate to equalization of payment that may be earned by workers on different jobs on which the time may not have been estimated with exactitude; how the price is reset when it is found that earnings of the workers are too high; what provision is made in the budget for the acquiring of skill by an unskilled operator on a new operation, with consequent increase in speed of production; and whether the predetermining of the production budget does not make the time-study department a guessing department and result in laxness of the time-study men.

J. C. MONTGOMERY[2]:—When the predetermined prices are put into effect and it is found that the workmen are running above the base rate that you want them to reach, do you make a closer study and then level the prices?

E. J. FROUNFELKER:—Generally speaking, we do not set a limit. If the cost has been set on a basis that is satisfactory to the management and it is met by the most sincere effort on the part of the operators, foremen, and superintendents, where we find a case of operators really earning too much we are willing to give them the benefit. We have very little rate-cutting or over-running of the budget figure.

MR. MONTGOMERY:—In your work you undoubtedly have one operation that is not identical with, but may run similar to, another, and if you have the wrong piecework prices established on one operation and have another operator close by who is not making so much money as the first operator, how do you avoid dissatisfaction among the workmen?

MR. FROUNFELKER:—By having a bonus system. All are paid the same percentage of bonus, with varying day-rates that are directly proportional to the value and speed of the operator.

If we desire to reduce the rate, which is not usual in the first 6 months of production, we consult the superintendent and the foreman, who put the proposal before the operator. In some cases, when we have enjoyed good production for a considerable time on the same model, the operators are willing to accept a little reduction in the rate. We do not make a practice of cutting the rates down to where the operators cannot earn much money, but they are willing to give and take to help keep the plant busy. In case of an operation being changed, of a new machine being installed, or of the company spending a large sum of money for, say, a power conveyor, or something like that, we do not change the rate except in cooperation with the superintendent, the manager and the foreman. We usually agree upon some terms under which the rate shall be revised. The budgeted figures usually are effective for a considerable time but we do not necessarily guarantee them nor do we call them temporary prices. They are simply the rate for the job, and several men have passed upon the job after the figures have left the time-study department. The cooperation of the men is asked in meeting these budget figures, and when there is cooperation of the time-study department, the management, the superintendent, and the foreman on the job with the operators, the operators will put their shoulders to the wheel and reach the budgeted figures. That has been our experience.

RATES CHANGED FOR INCREASED PRODUCTION

MR. MONTGOMERY:—So long as you are producing at less than the direct-labor estimate, are you satisfied to let the cost run as it may?

MR. FROUNFELKER:—Yes, for a considerable time, unless something develops, such as an increased schedule; perhaps a new customer will want a model that is practically the same as one on which we are running, in which case the job will be slightly retooled for the increased production and, of course, we get lower unit-costs when we have higher production.

R. A. TOWNSEND[3]:—How many rates is it necessary to predetermine for an average six-cylinder engine and what department lists the operations?

MR. FROUNFELKER:—Although I have not the exact figures available, I should say that the number of piece prices it is necessary to set for each six-cylinder engine is in the neighborhood of 85. There are more than 85 different operations but we have the total price set per

[1] The paper was printed in THE JOURNAL for October, 1927, p. 386. The author is connected with the manufacturing division, Continental Motors Corporation, Detroit. The original abstract of the paper is reprinted above, supplemented by a summary of the major points dealt with in the discussion.

[2] Assistant superintendent, Hayes Hunt Corporation, Elizabeth, N. J.

[3] Metallurgist, Van Dorn Iron Works Co., Cleveland.

piece; that is, the price which is paid to the group, so much money for a given finished product.

The department that lists the operations would depend more or less upon the layout of the shop. The cylinder department may be divided into one, two, three or four groups, and we issue a corresponding number of rates. In the small-parts department, which works on valve-stem guides, water-pumps, propellers, pump shafts, and automatic work, a great number of prices on different jobs are set.

The Group Price Levels Piece Rates

A MEMBER:—Do you not think that predetermining the price makes a time-study man lax about trying to lower the cost? He might know that the price for a job would be within your range and still be twice as high as it should be, because of misjudgment of the management, which often happens, and he would let the price stand. Sometimes you would be paying two and three times as much for a product as should be paid for it. The operator would notice that and would nurse it along. It is hard to catch him at it.

MR. FROUNFELKER:—We must first consider that there are several men in the time-study department who arrive at these costs originally. Then the prices are submitted to the production engineer, who has been through the time-study work and knows it thoroughly, and are submitted to the superintendent, who knows from experience the time it takes to perform a given operation. I believe there never has been a manager of a factory who has not been through the time-study work in one way or another and while at times it is difficult to estimate the times yet when they are estimated on a fundamental basis, such as speeds and feeds, chucking and unloading time, for the machine on which the operation is performed, it is very unlikely that many operations will be timed for only half of the capacity of the machine and the operator.

In case a figure should be set a little high, it can be counterbalanced by having a group price on the job, because, if the estimate on one operation is high, the estimate on another will be low and the total price, by the law of mathematical averages, should come very close to being correct.

Budgeting Is Not Rate Guessing

A MEMBER:—When you do that, however, I think you are ruining the motive of the time-study; you are putting guess-work into it.

MR. FROUNFELKER:—Our experience has not proved that it is making a guessing department out of the time-study department; we are confronting the time-study department with the obligation to explain why a job is not meeting the predetermined price. If the price is not predetermined, no task is set for the time-study man. I should say that predetermining the price puts him on his toes almost to the ultimate. He has to think to be able to suggest some way of improving the operation that is not producing as many pieces per hour as has been estimated and budgeted.

A MEMBER:—You could not ask the time-study man to figure what a tool designer is going to design; that is impossible.

MR. FROUNFELKER:—I think we partly cover that when we submit the time-studies to the tool division before the tools are made for the job. The chief tool designer, who reports directly to the production manager and to me, raises the question very often whether it is possible to machine a given operation in a specified time. In that case, if we find it impossible to design a fixture such as we anticipated in a meeting, we can change our budgeted figure before it is announced, because the tools have not been designed.

EDWARD W. BERNHARD[4]:—It seems to me that some of us may miss the point of the paper. Suppose this particular company were starting up new and had no time-study records; it probably would take 50, 60 or 100 time-study men 2 years to accumulate a mass of data. If you were manager of that plant, at the end of the 2 years you would have a rather large expense charged to time-study work and would ask yourself, "Am I getting value received from all of this time-study?" At the Continental plant they are not making the time-studies again and again, like a payroll; they work a shortcut. They say, "We have all the data; what is the use of doing it all over every day?" They look only for the exceptions, which take but a few minutes to find, and very few time-study men are needed to take care of the work.

CHAIRMAN EUGENE BOUTON[5]:—Mr. Frounfelker has pointed out some very interesting phases of budgeting which can be applied to almost any industry. Budgeting has been the target for frequent attacks by many executives as being more or less a guess, or unreliable and theoretical. It probably is true that budgeting is not an exact function of management, but anything which tends to increase efficient management, decrease costs, and so on, is worthy of further study and adoption even though it may not be perfect in its application.

Time-study has a very important bearing on the basis of establishing budgets. It is the foundation for labor costs, both direct and indirect; it establishes to a reasonably close estimate the amount of shop supplies and equipment necessary to produce a given schedule, and, when this is done, budgeting is placed on a more scientific basis. There have been cases in which budgets were established by rule-of-thumb methods and guess-work, and the opponents of budgeting have cited these cases as being failures, which no doubt they are. Each manufacturing company has its own peculiar problems to deal with, and using time-study as a basis or foundation to fit the manufacturing conditions will produce satisfactory results in the handling of budgets.

Problem Created by Acquirement of Skill

A MEMBER:—One element which would be expected to have a great deal to do with time-study has not been touched upon. I mention this because, in my particular branch of the work, it is most important.

I have to do with assembling operations on conveyors, trimming and final assembly in which machine-tools do not figure very much. The element of personal skill constitutes about 90 per cent of the problem. The great problem of my life has been to try to predict how much a man can speed-up a certain operation which perhaps has never been done before, or which the man never has done before, because it is the custom largely to employ unskilled or only partially skilled help. It has been my observation that operations which an operator, when he started, would swear he could not do at the rate of 10 per hr. would be done at a rate of 100 per hr. after he had been at it 3 months.

That one element of rapidly increasing speed as the operator becomes more skilled is the reason we have to be constantly reducing rates in our particular line of production. The predicting of operators' speeds is not easy for us, but we do apply the same principles that

[4] M.S.A.E.—Manager of automotive equipment division, L. H. Gilmer Co., Wayne, Mich.

[5] M.S.A.E.—Supervisor of time-study, Chandler-Cleveland Motors Corporation, Cleveland.

have been applied in Mr. Frounfelker's work; that is, we can determine to some extent, from the speeds with which similar operations have been performed, what our ultimate speed on a certain operation will be. Owing to the fact that we do not intend to put skilled operators on the work at the start, we are forced to place a more or less temporary rate thereon. We know it will be impossible for the conveyor to function at anything like the maximum rate at the beginning, so we have a somewhat different problem from Mr. Frounfelker's.

MR. MONTGOMERY:—You may include in the budget an amount of $25 for the job; for the first month the cost may run $35; the next month, through a process of elimination of dead wood and through speed acquired by the operators, the cost may come down to $20. That cannot be controlled. No matter how closely you estimate, you are going to have a variation above or below the estimate on work that is not controlled by machine mechanics.

MR. FROUNFELKER:—This is the way we get around that. We have operations that take considerable time for an operator to become sufficiently skilled to perform the work at a satisfactory pace. A new employe on such an operation is employed at a lower base-rate than that of the skilled operator. He receives the same percentage of bonus but it is on his lower base-rate. Therefore, his total earnings are lower than those of the skilled operators and consequently our costs are more or less constant. When an operator becomes proficient we have no difficulty in putting raises through for him on his base rate, because the higher rate does not change our total cost; it merely changes the prorating of the operators in the group, and a man is paid in proportion to the amount of work he turns out in a day. By starting him at a low day-rate, putting him in the group, and giving him the same percentage bonus, we do not pay him as much money for the same length of time as he would get as a skilled operator.

We have some extremely difficult operations on which we allow the man 3 days, to be paid for by the company and not by the group, to become proficient on the operation, before we give him a base rate in the group. This payment is distributed in our accounting department to labor-turnover cost.

The Motor Liner

FOR some time there has been more than a suspicion that the motor liner would come very rapidly when it did begin to come and that the first sign of its real establishment as an important factor in passenger service on long-distance ocean routes would be the ordering of repeat vessels by firms that already had experience with one ship of the type. This sign has now been given more than once. It was given by the Royal Mail Steam Packet Co., Ltd., when it placed with Harland & Wolff, Ltd., of Belfast, the order for the Alcantara, in succession to that for the Asturias; and it was given by the Union Castle Mail Steamship Co., Ltd., which ordered from the same firm a duplicate of the Carnarvon Castle.

The three vessels mentioned are practically sister ships, so that, as the two owning-companies are closely associated, there will be, perhaps, a year and a half hence, a homogeneous group of four, each of about 20,000 tons gross and 20,000 i.hp., with splendid accommodation for about 1500 passengers, and equals the finest steamliners on any route.

There may also be quoted the action of the Swedish-America Line in ordering from Hamburg a repeat of its Tyne-built Gripsholm; and it may be noted, as a matter of special engineering importance, that all the half-dozen vessels have, or will have, twin-screw machinery of the Burmeister & Wain, eight-cylinder four-cycle double-acting type, the installations of the Swedish vessels coming from the works of the parent firm in Copenhagen, and those of the British ships from the shops of their builders, Harland & Wolff, Ltd.

At present the pace is being made by this type of engine, but it is said that there is in prospect an order by the New Zealand Shipping Co. for a repeat of the Aorangi, which has quadruple-screw single-acting Fairfield-Sulzer engines and has proved to be one of the most successful vessels on service on the Pacific. If this order is placed, the motor liner will have "arrived" in real earnest, and the turbine will have to look to its laurels more seriously than ever.—*Modern Transport* (London).

Window Washing Saves Waste

ARTISTS for many hundreds of years have known that a north light is essential for good workmanship both in regard to composition and color. But industry is so much younger than art, and has been so much concerned with the rapid developments within itself along the lines of scientific improvement of machines to reduce man's drudgery, that it is comparatively recently that any real attention has been given to a scientific study of the relation between good work-light and both the quantity and quality of production.

In planning factory and office buildings, careful thought is given to getting the maximum daylight possible, and then beyond that to provide good artificial lighting that will not only save workmen's eyes but speed-up production and cause fewer rejects or mistakes in work.

Cost experts have shown that window-washing expense represents but a very small fraction of the actual waste which occurs when bad lighting prevails. Even the electric-lighting costs have been reduced by the adoption of good reflectors, by washing bulbs and reflectors regularly, and by having light-painted walls that are cleaned regularly so that the full value of reflected light is obtained.—*Oakite News Service.*

Continuation of the 1922 Report on Brake-Lining Tests[1]

By S. VON AMMON[2]

SEMI-ANNUAL MEETING PAPER *Illustrated with* DRAWINGS, PHOTOGRAPHS AND CHARTS

A REPORT on the investigation of brake-lining materials by the Bureau of Standards was made by the author in 1922. The present paper gives information on work done in this field since that time. It places on record a summary and discussion of various test-methods and equipment at present employed by brake-lining manufacturers and others in the automotive industry. The difficulties connected with this work, resulting from the varying characteristics of brake-lining materials, are brought out. It is shown that some of the test methods in use do not furnish a basis for ready or fair comparison of different brake-linings. Other test procedures are so limited as to give only an incomplete picture of the characteristics of the brake-linings under conditions met in service; therefore, the test schedules generally require readjustment and amplification because a full and satisfactory knowledge of these materials can be obtained in this manner only. Finally, the essential features to be given consideration on the basis of present knowledge are reviewed and proposals are made which it is believed should, with reasonably limited tests, give a satisfactory picture of the character of brake-linings and a comparison of their relative merits.

IN an earlier paper[3] I reported on work done at the Bureau of Standards during 1921 in connection with developing methods and equipment for testing brake-linings for automotive vehicles. The objects of this work were to obtain a basis for specifications for Government purchases of such linings and to establish acceptable standard methods for such tests. This early work of the Bureau, while not conclusive, achieved one of its purposes insofar as it demonstrated wide differences in the behavior of different materials marketed at the time and thus led manufacturers to more systematic laboratory tests. These in turn helped toward a better understanding of the influence of various factors in the design and composition of brake-lining and in manufacturing methods and their control, which again has led to the production of greatly improved brake-lining materials.

Since 1922, much knowledge has been gained in regard to the design of brakes as well as the possibilities and limitations of brake-linings. It is true that the demands on braking systems have been increased greatly to meet the needs of heavier vehicles, higher operating-speeds, more stringent traffic regulations and a desire for more uniform, smoother and more quiet operation. The brake designer has applied his better knowledge of the fundamentals of brake operation, and has given more attention to the design of the brake system in all its parts. Among other results it is now also appreciated better than formerly how far the responsibility for satisfactory operation should properly rest on the brake mechanism, and what may reasonably be expected from the brake-lining materials. In spite of this the brake-lining manufacturer and the user find some difficulty in determining the characteristics of linings under the conditions to be met as governed by a great variety of brake and car designs and road operating-conditions.

Such determinations must start in the laboratory on the brake-lining itself, uninfluenced by such factors as brake design and its compromises and road conditions.

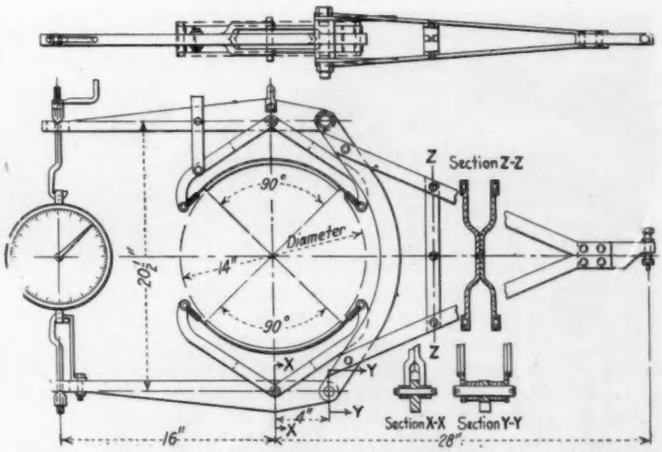


FIG. 1—ORIGINAL EQUIPMENT OF THE BUREAU OF STANDARDS FOR TESTING BRAKE-LININGS

Road tests in which a lining may give final account of itself under all conditions met in service, resulting all the way from the design of the brake system to conditions of the road and the influence of the latter on the former, certainly will continue to be necessary. Information of value on features of brake design as well as on the requirements to be met by linings for best results with any given brake also can be obtained by laboratory tests of brakes and linings combined, either with an individual brake or with the entire braking system of a given vehicle on its chassis.

Finally, the brake-lining manufacturer must return to his laboratory equipment for testing linings, as such, so that he can learn the explanation of every peculiarity found in service and that he can, on the other hand, constantly check his product to maintain as nearly as possible its absolute uniformity and reliability. Present laboratory-test methods are admittedly not yet developed to the point to aid both manufacturer and user in a wholly satisfactory manner.

It is not the purpose of this paper to announce any

[1] Published by permission of the Director of the Bureau of Standards, City of Washington.

[2] Mechanical engineer, Bureau of Standards, City of Washington.

[3] See THE JOURNAL, March, 1922, p. 153.

FIG. 2—IMPROVED EQUIPMENT FOR TESTING BRAKE-LININGS, DESIGNED AT THE BUREAU OF STANDARDS IN 1922

Two Sets of This Equipment Were Put into Operation during the Spring of 1923

striking advance or to offer the ultimate in test methods, but rather to present a report on work done at the Bureau since 1921. In this connection it seemed advisable to study as far as possible the work done by others than the Bureau, as to both test equipment and procedure; and, in line with the suggestion coming from the Society, the present paper includes a summary of this work and the results gained. The presentation of this material and the discussion of it should help to clarify the situation, contribute to overcoming existing difficulties and, possibly, misunderstandings, and assist generally in determining eventually upon wholly satisfactory test methods.

EQUIPMENT AND METHODS IN GENERAL

Description of equipment and methods in use at present will be limited to laboratory tests for ascertaining durability, and the value and uniformity of the coefficient of friction. Such equipment does not vary in basic principle. In the machines found in use recently, a few of which were used before the Bureau began this investigation, one or more brake-shoes lined with a sample of the materials to be tested are applied to a rotating drum. The machines differ in the size and type of drum, the type and number of shoes, the size of specimen, and the means for determining the pressure,

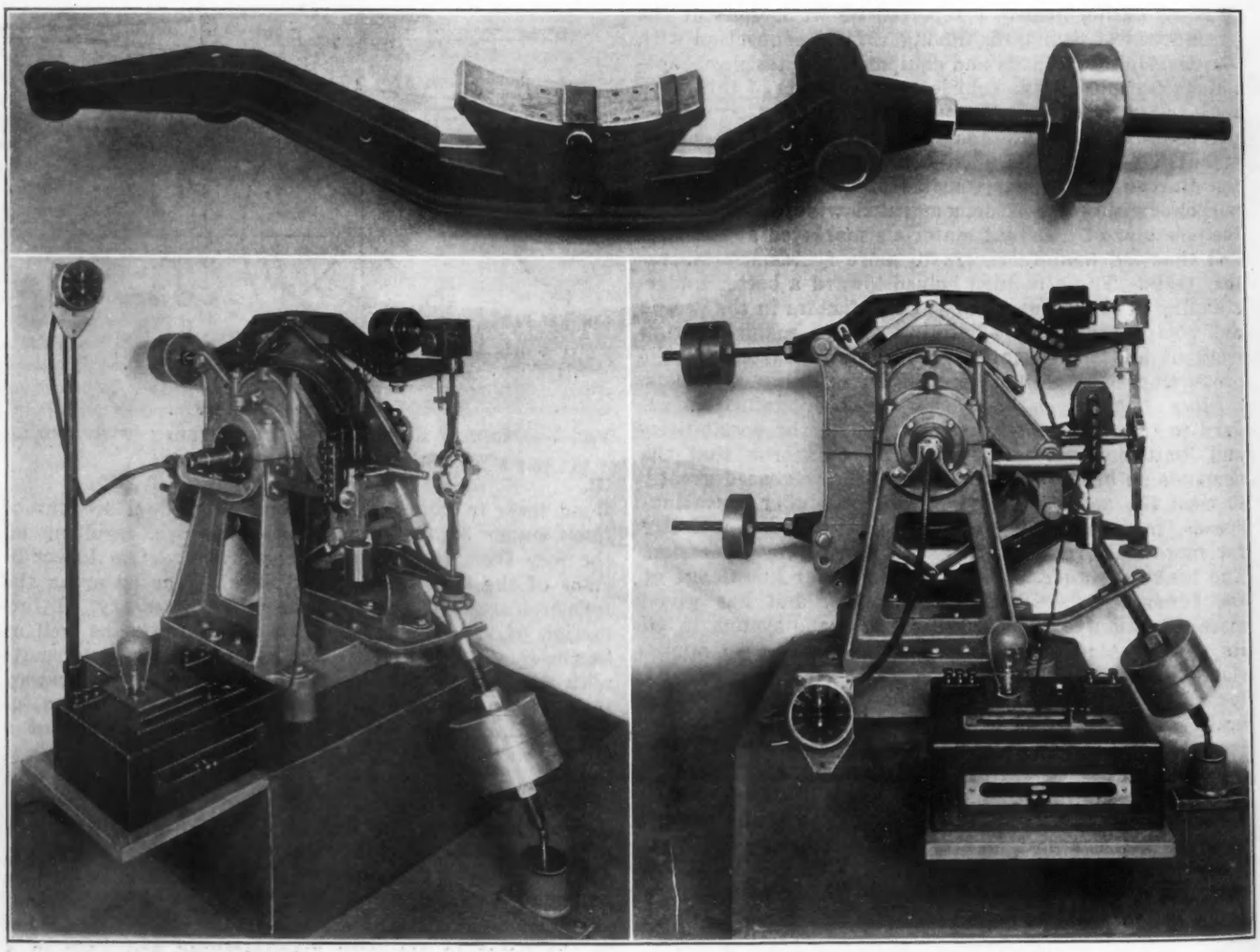


FIG. 3—EQUIPMENT FOR TESTING BRAKE-LININGS AS USED AT THE BUREAU OF STANDARDS SINCE 1925

Two Views of the Equipment Are Shown. Solid Brake-Shoes Similar to the One Shown in the Upper View Have Been in Experimental Use for Some Time

torque, horsepower absorption, coefficient of friction and wear. The tests are made either with constant horsepower-absorption or with constant brake-shoe pressure during the period of application. In either case, the applications may be continuous or intermittent. The drum temperature is in some tests limited by water-cooling, or in others controlled to a less extent by providing more or less cooling-surface and windage, or by the use of intermittent tests with various periods of application. Some of the features of design are a matter of convenience, or affect the cost of the equipment to some extent.

The test procedure itself can be varied considerably provided the conditions remain reasonable; but every variation in procedure makes it difficult to compare the several results and is apt to cause confusion. The temperature has an important influence on the behavior of brake-linings as used in automotive work. The coefficient of friction may vary over a wide range either in the same lining or as between different linings. If the pressure during a test is kept constant, every change in the coefficient of friction causes a change in the power absorption which, in turn, affects the temperature; this again reacts on the coefficient of friction. Every change in load and temperature may again affect the rate of wear. Thus, with the constant-pressure test, it becomes very difficult to judge correctly the qualities of a lining and impossible to make comparisons of value as to the relative durability of different linings. Concerning some of the other details of test procedure, it is still doubtful to just what extent they may or may not have advantages.

[4] See THE JOURNAL, March, 1922, p. 153.

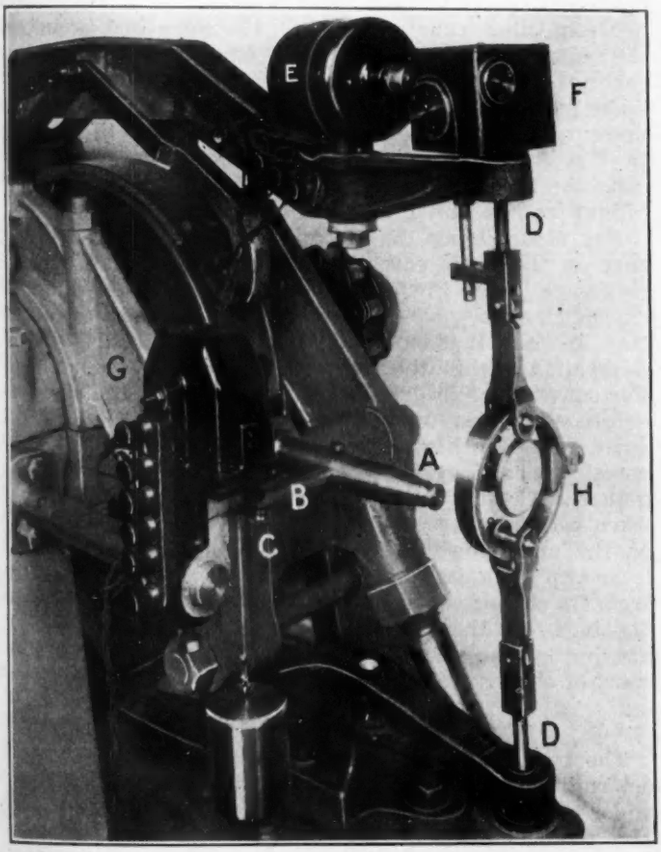


FIG. 4—EQUIPMENT FOR SECURING AUTOMATIC PRESSURE-REGULATION

In Testing the Pendulum for the Torque Corresponding to the Desired Power-Absorption and Speed, a Balance Is Attached to the Groove in the Calibrating Arm Shown at *A* for Measuring the Over-Balance of the Oscillating Yoke under the Normal Conditions as Indicated by the Pointer *B* on the Scale *C*. To Damp Oscillations of the Yoke, from Whatever Cause, a Dashpot Is Connected with the Ends of the Pendulum. Stops Limit the Up-and-Down Movements of the Weighted Arm

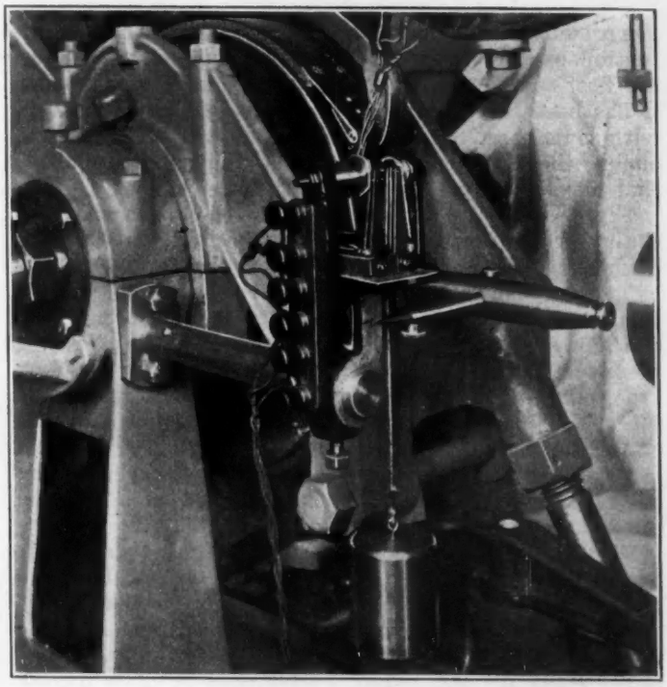


FIG. 5—CAM-OPERATED DOUBLE-THROW SWITCH

The Switch Shown at *G* in Fig. 4 Is Here Shown with the Cover Removed. It is Actuated by the Pointer on the Yoke Through a Weighted Cord Running Over a Pulley on the Camshaft

BUREAU OF STANDARDS TESTING-EQUIPMENT

The original testing-equipment of the Bureau was built in 1920 and is fully described in my 1922 paper[4]; but it is shown again in Fig. 1 because a number of these machines are still in regular use. This equipment, purposely made as simple as possible, proved useful in the preliminary work. The results obtained with the equipment fully justified its further development so as to assure more reliable operation, to improve the ease of handling and to eliminate some of the variation in results obtained by different methods of operation.

When planning improved test-equipment it was thought best to make only such changes as, from information available, promised definite advantages, and to leave other features so that the general test-conditions originally decided upon could be duplicated, and accumulated test-data could be utilized. Otherwise, the first improved model and the present one were arranged to leave them adaptable to a variety of minor changes in regard to the size and number of test-specimens, type of brake-shoes and brake-drum, and the like.

The improved equipment designed at the Bureau in 1922 is shown in Fig. 2. Two sets of this equipment were put into operation during the spring of 1923. Some features of the equipment resulted from the use of available material and space; and it was, on the other hand, designed so as to permit a try-out of various modifications. It proved satisfactory in regular use over a long period. It was redesigned in the fall of 1924. The principal changes made at that time consisted in converting it into a self-contained individual unit, improving a number of structural features and including

some additions to facilitate the operation with less attention by the operator. Since the fall of 1925, when the first set of this model was completed for operation, it has been in regular use; the four sets now available, with some possible minor adaptations will, it is believed, enable the Bureau to meet every important condition that may be found desirable in the laboratory.

Fig. 3 shows a three-quarter view of this machine, at the lower left, and an end view at the lower right. The double yoke carrying the brake-shoes on lever-arms oscillates on ball-bearings supported by housings carried in the pedestals, which also contain the shaft bearings. With this central method of supporting the yoke, it was possible to make the machine of the weighted-pendulum type, eliminating the platform scale as used originally for measuring the torque reaction. The drum shown is of the same size, type and material as used earlier, being 14 in. in diameter and composed of low-carbon steel; but, for this, drums of widely different material and construction can be substituted.

Fig. 3 shows the machine equipped with two flexible brake-shoes and with a test-specimen 11 x 2 x ¼ in. riveted to each, as originally used; but one such shoe only, or one or two shoes of the solid-block type, can be used instead. Solid brake-shoes similar to the one shown in the upper portion of Fig. 3 have been in experimental use for some time, but may undergo further change.

The lever-arms carrying the brake-shoes are balanced by means of adjustable weights on the threaded extensions of the arms, one being shown in the upper portion of Fig. 3. The large weights on the pendulum are also adjustable so that the machine can be set for a power absorption varying over a wide range. In adjusting the pendulum for the torque corresponding to the desired power-absorption and speed, a balance is attached to the groove in the calibrating arm, shown at *A* in Fig. 4, for measuring the over-balance of the oscillating yoke in the normal position as indicated by the pointer *B* on the scale *C*. To damp oscillations of the yoke, from whatever cause, a dashpot is connected with the end of the pendulum. Stops limit the up-and-down movements of the weighted arm.

The pressure on the brake-shoes is adjusted by means of the studs shown at *D* in Fig. 4, the handwheel on the lower one being used for coarse adjustment when desired. When the machine is equipped for hand adjustment only, another handwheel is arranged on the upper stud. To reduce the attention required in operation, automatic regulation of the brake-shoe pressure is provided as shown in the illustrations. This automatic regulation is performed by equipment which, as shown in detail in Fig. 4, includes a small electric motor *E*, connected through a spring coupling and the worm-gear speed-reduction box *F* with the upper stud *D*. A cam-operated double-throw switch *G*, which is shown also with the cover removed in Fig. 5, is actuated by the pointer on the yoke through a weighted cord running over a pulley on the camshaft. Any increase or decrease in the torque on the yoke resulting from a change in the coefficient of friction, or from wear of the brake-lining or from other causes, displaces the yoke and actuates the control switch. This closes the motor circuit for forward or reverse operation for the time required to make automatically the necessary adjustment in the pressure on the brake-shoes. The control box illustrated in Fig. 3 permits adjustment in the motor circuit to meet the requirements of tests under different load-conditions or line voltages.

For ascertaining the coefficient of friction, the pressure on the brake-shoes is measured by means of the ring-gage *H* in Fig. 4. This instrument, in which a micrometer dial-gage measures the distortion of the steel ring in which it is mounted, is not subject to changes in calibration within the limits for which it is designed. For convenience in grinding the drums to a true surface before every test of a brake-lining, a grinding attachment, shown in Fig. 6, is provided. This consists of a portable electric grinder and a slide-rest mounted together on a substantial bracket. To replace the drum when necessary, access is obtained by removing the caps on the underside of the yoke, disconnecting the lower lever-arm with its shoe and lifting the yoke complete from its supports. The shaft complete, with its bearing housings, can then be removed. The left-hand bearing-housing is then removable as a unit, permitting replacement of the drum.

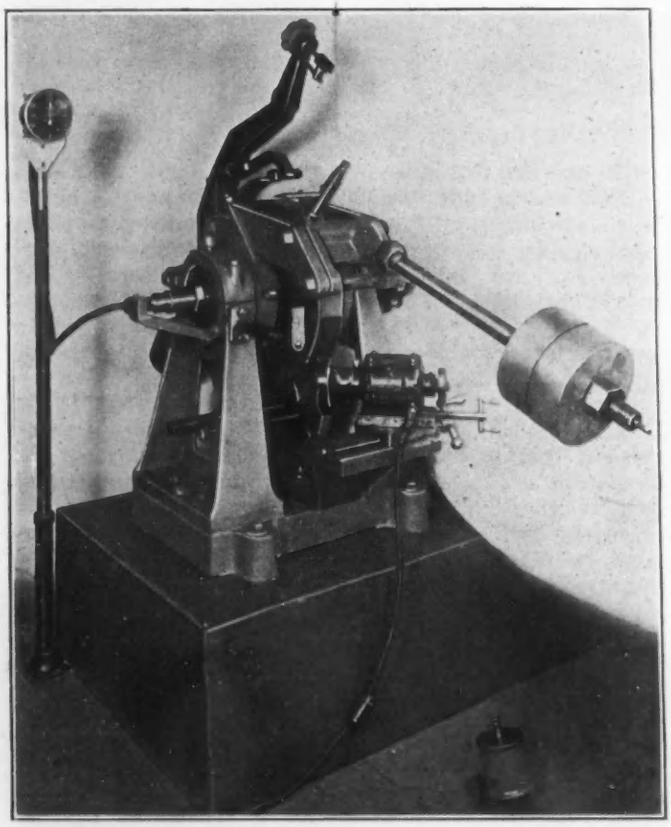


FIG. 6—GRINDING ATTACHMENT FOR BRAKE-LINING-TEST EQUIPMENT

For Convenience in Grinding the Drums to a True Surface before Every Test of a Brake-Lining, the Grinding Attachment Shown Is Provided. This Consists of a Portable Electric Grinder and a Slide-Rest Mounted Together on a Substantial Bracket

BUREAU OF STANDARDS TESTS

The two principal tests planned originally were for determining the durability and coefficient of friction under moderate and under severe conditions, respectively. The power absorption has always been kept constant during any test. In the less severe of these two tests the drum temperature was restricted by internal water-cooling of the drum to one approximating that of boiling water. Under these conditions, only moderate changes in the coefficient of friction of the dry brake-lining are shown. As explained in the earlier report, difficulties arising under these test conditions made it advisable to abandon the test in this form.

Preliminary work with the severer test resulted in selecting a power absorption of 6 hp. at 600 r.p.m. These conditions showed the very considerable variations which could occur in the coefficient of friction, and permitted the wearing of the ¼-in. specimens, within a reasonable time, to a thickness of ⅛ in., at least for all linings then available.

In its routine work the Bureau has continued to employ the severe-service durability-test so as to utilize the accumulated test-data and because no fully satisfactory substitute has been available. This test is admittedly open to the criticism that its conditions are more severe than those usually occuring in service. While it has never been the intention to use this test alone, it has nevertheless served a useful purpose in connection with Government purchases of brake-linings in eliminating from consideration those linings less able to withstand extreme conditions which may and do at times occur. This severe-service test has also helped to make available linings of remarkably improved durability under the severest operating conditions and high temperatures. Thus, of those tested in 1921, the 12 brake-linings proving most durable under the conditions of this severe-service test showed an average wear-factor of 601; while the average wear-factor of the same number leading in durability had, a year later, dropped to 208 and in 1926 it had again dropped to 33.

The results of this severe-service test also furnish a fund of information on the changes which may occur in the coefficient of friction under varying conditions, although some of the details may not be readily apparent without careful analysis. In this severe-service test several pieces of the same lining occasionally show variations in durability. Evidence is available that these differences result not from test equipment or conditions but from the lining material itself, or from variations in it, although, possibly, interaction between lining and drum material may also have some effect.

The main difficulty experienced in the early work with the tests with a water-cooled drum was due to the collecting of steel cuttings from the drum in the brake-lining. Specimens from these tests showed that an oozing or bleeding of the saturant occurred and this material held the particles of steel which might accumulate during the progress of the test and, presumably due to locally high temperature, might be combined into smaller or larger solid bodies of metal. On account of this and other more general objections to the water-cooled test, it was desirable to develop a moderate durability-test which would give temperatures higher than those occurring here, but sufficiently low to approximate those experienced in moderate service. A series of tests made in 1922 with loads of from 1 to 6 hp. at 300 and at 600 r.p.m. gave the results shown in Fig. 7. A further more limited group using both one and two brake-shoes and test-specimens was also made later, but yielded little additional information.

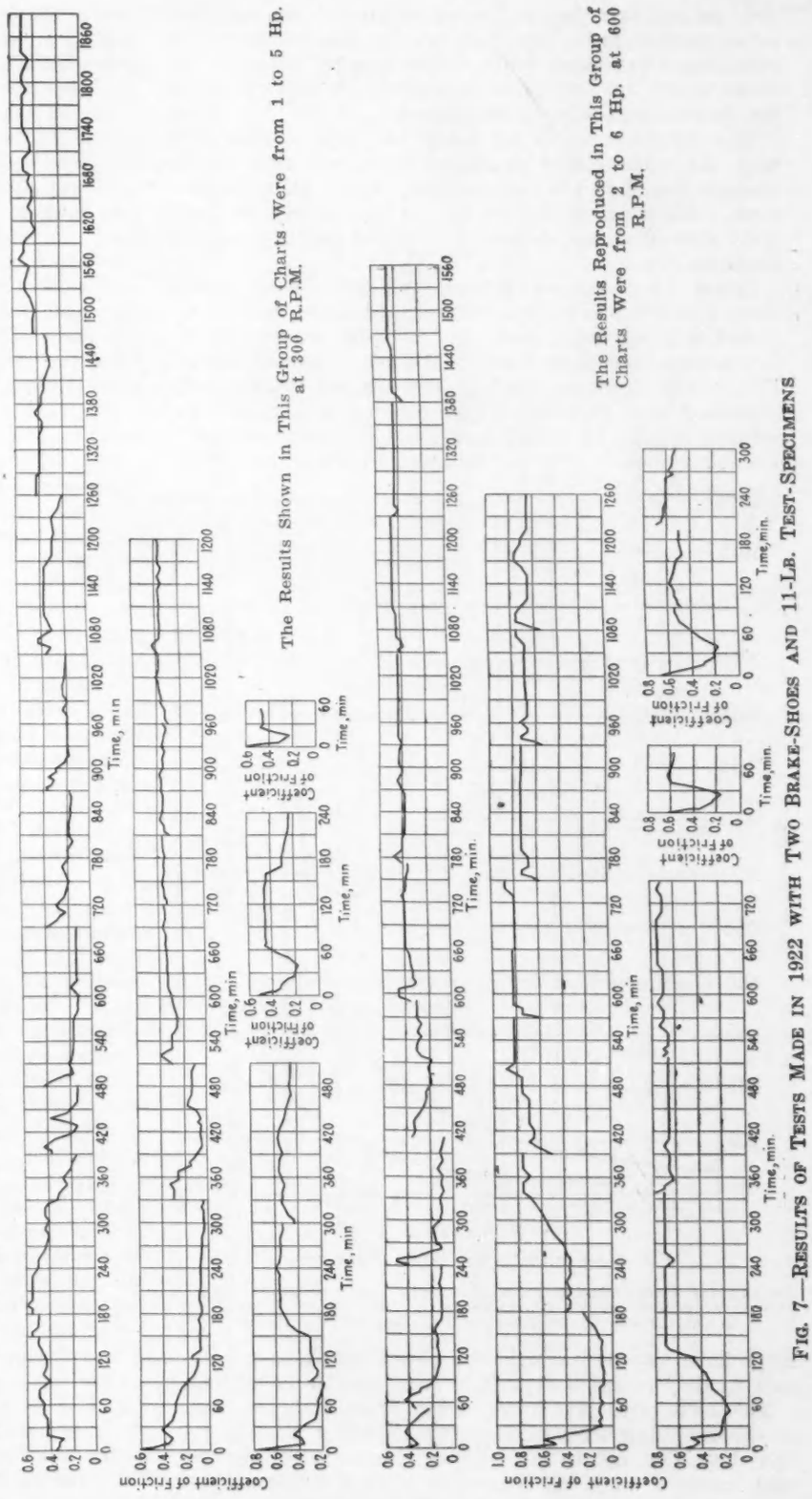

The Results Shown in This Group of Charts Were from 1 to 5 Hp. at 300 R.P.M.
The Results Reproduced in This Group of Charts Were from 2 to 6 Hp. at 600 R.P.M.
Coefficient of Friction
Time, min

FIG. 7—RESULTS OF TESTS MADE IN 1922 WITH TWO BRAKE-SHOES AND 11-LB. TEST-SPECIMENS

It will be observed from Figs. 7 and 8 that, with lowering of the power absorption, the wear is reduced materially; but changes in the coefficient of friction are closely similar in all cases up to the maximum load of 6 hp. at

600 r.p.m., this being the condition of the original severe-service test. Fig. 8 shows the wear-factor values resulting from these tests. The greater wear at the lower speed for any given horsepower is due chiefly to the decreased cooling at this speed.

The temperature in all cases was higher than that with the water-cooled drum, as evidenced also by the changes found in the surface condition of all test-specimens. Even so, a number of the less severe of these tests showed an accumulation of metal particles on the brake-linings.

Lower temperatures approaching still more closely those occurring with the water-cooled drum can be obtained, without going down to 1 or 2-hp. absorption, by increasing the cooling through the use of special drums. This would, however, tend to increase the trouble with embedded steel-particles. The rate of wear would be reduced to such an extent that the test would require a prohibitive length of time. Changes in the design of the drum have also been considered objectionable in proportion as they meant a departure from service conditions.

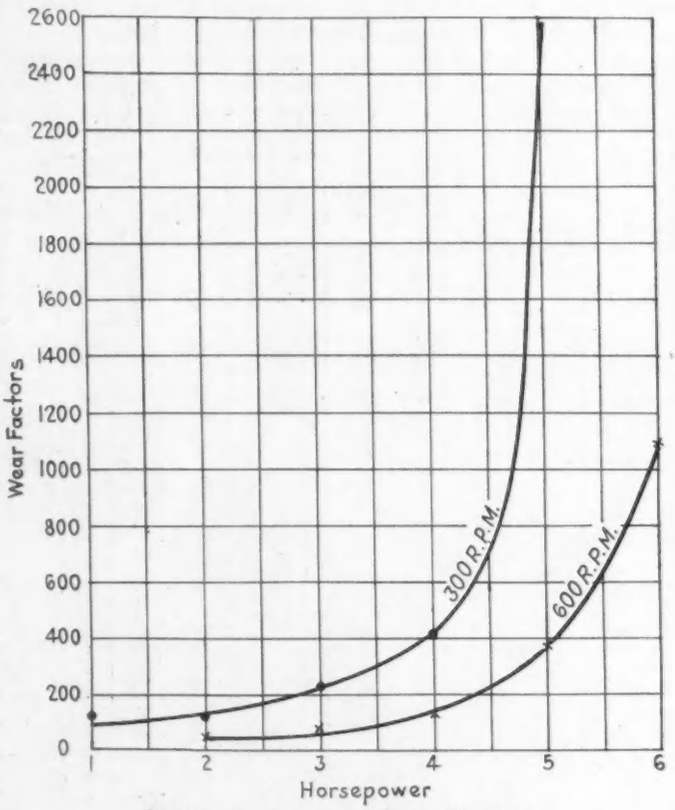


FIG. 8—RELATION OF WEAR FACTORS

The Values Shown Result from the Tests Represented in Fig. 7. The Greater Wear at the Lower Speed for Any Given Horsepower Is Due Chiefly to the Decreased Cooling at This Speed

The tests with the water-cooled drum indicate that, at the resulting temperatures, the bleeding already referred to does not cause—although an accumulation of bled material may, at somewhat higher temperatures, accentuate—a lowering of the coefficient of friction. The bleeding is apt to cause the brake-lining to stick to the drum when the warm band is left applied. These features led manufacturers to minimize this tendency to bleed by reducing the percentage of saturant or by the use of other saturants. The tendency to accumulate steel on the brake-linings, while probably less marked now than formerly, is still being experienced with water-cooled drums with some of the test methods and linings used. Since the Bureau has secured more adequate facilities, additional work has been undertaken to find more satisfactory test-conditions for demonstrating both the variations in the coefficient of friction and the durability of any brake-lining.

For the brake-lining materials in general use available data show that, within the range of temperatures and unit pressures which occur in the operation of automotive brakes, the sometimes large changes in the coefficient of friction are brought about almost entirely by temperature conditions and are practically if not entirely independent of the pressure on the material. Within the same range, the influence of high temperature and the changes resulting from it are also far greater factors than the pressure in determining the durability of a given lining.

One part of the work referred to has therefore been concerned with ascertaining the range of temperature which, without our equipment, would result from a large number of combinations of power absorption, speed and size, and number of test-specimens. No changes have so far been made in the drum or in its material, nor has it seemed advisable to reduce operating temperatures by increased air-circulation either with vanes on the drum, an air-blast or other means subject to possible variations difficult to check. To assist in cooling the sample and on account of the greater adaptability to the use of test-specimens of varying sizes and other advantages, solid brake-shoes of aluminum, as shown in Fig. 3, have been used in addition to the original type of flexible-band brake-shoes. Observations of the temperatures have been made with both one and two brake-shoes of both types at 300 and at 600 r.p.m. with test-specimens from 2 to 6 in. long on the solid shoes and the full 11-in. test-specimens on the flexible shoes. The temperatures obtained after reaching equilibrium in each test are useful in determining those of the test conditions with which it seems desirable to proceed. A partial series of complete durability-tests under some of the conditions already mentioned has also been made with samples of one brake-lining. While this series is incomplete and some of the results are inconsistent in some respects, a few of the results may be of interest.

Fig. 9 shows, in the upper portion, a group obtained with 2 and 3 hp. at 300 r.p.m. with two test-specimens of respectively 3-in. and 4-in. length on the solid shoes in each case. The lower portion of Fig. 9 shows a group with the same conditions except that the speed was 600 r.p.m. In this latter group the record of only the first part of the test is given, but the wear factors indicate the relative rate of wear. Fig. 10 shows the results with only one solid brake-shoe with a 6-in. test-specimen and 3 hp. at both 300 and 600 r.p.m.

For comparison, the results of the present routine severe-service test with two 11-in. test-specimens on the flexible brake-shoes and 6 hp. at 600 r.p.m. are given in Fig. 11. It will be noted that the coefficient of friction under some of these less-severe test-conditions reaches depths not found in earlier tests with similar material. The temperature and rate of wear are considerably lower at 600 r.p.m. than at 300 r.p.m. for the same power absorption. The rate of wear with the short test-specimens is in some cases considerably lower than with the original 11-in. test-specimens; in others, it is higher. The condition of the brake-lining after the test showed much less penetrating impairment than the regular severe-service tests showed. The working surface was discolored by heat, but it was smooth. The lining used carries very little saturant; so, the surface after test is

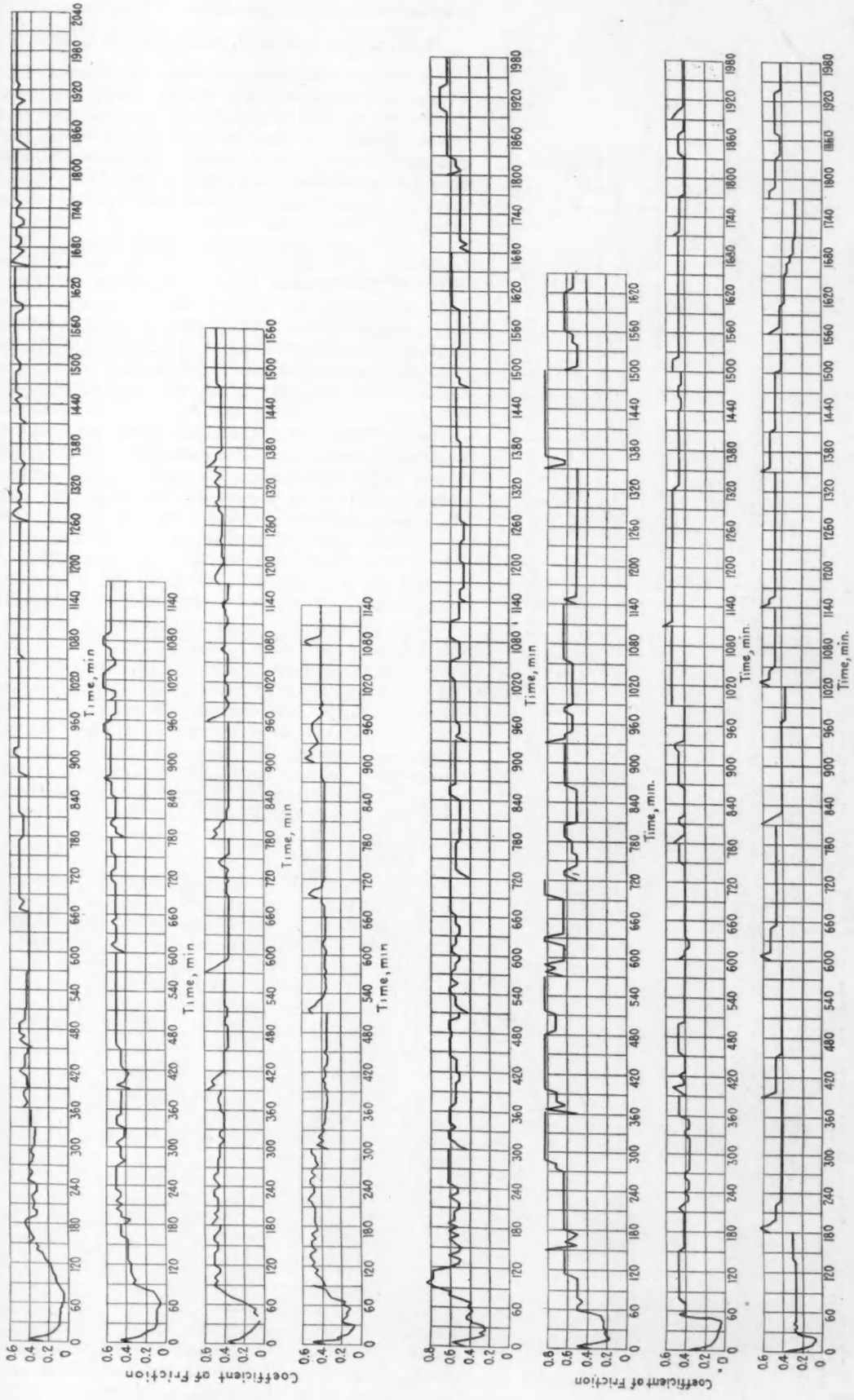


FIG. 9—RESULTS OF TESTS USING TWO SOLID BRAKE-SHOES AND TEST-SPECIMENS 3 AND 4 IN. LONG RESPECTIVELY

A Partial Series of Complete Durability-Tests Was Also Made with Samples of One Brake-Lining. The Series Is Incomplete but Some of the Results Are Shown. Those in the Upper Portion Are for 2 and 3 Hp. at 300 R.P.M. For the Results Shown in the Lower Portion, the Speed Was 600 R.P.M.

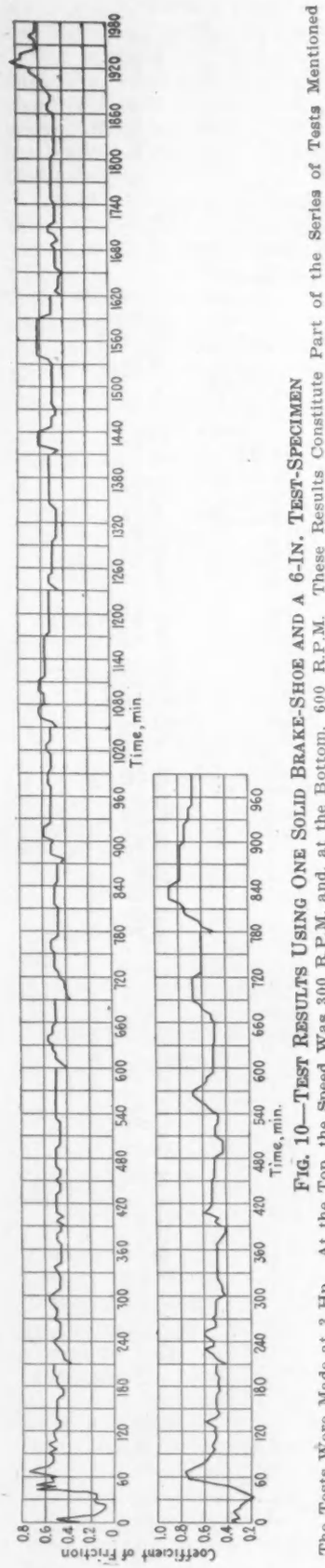


FIG. 10—TEST RESULTS USING ONE SOLID BRAKE-SHOE AND A 6-IN. TEST-SPECIMEN

The Tests Were Made at 3 Hp. At the Top, the Speed Was 300 R.P.M. and, at the Bottom, 600 R.P.M. These Results Constitute Part of the Series of Tests Mentioned for Fig. 9

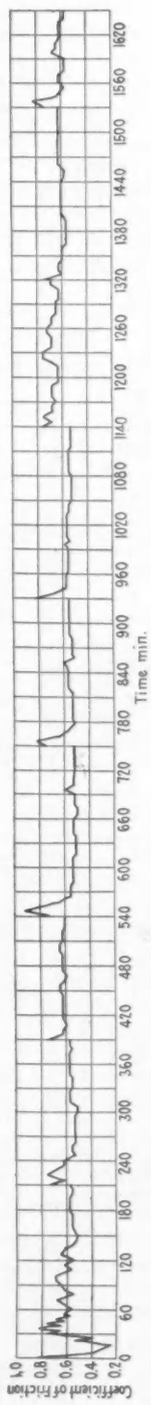


FIG. 11—RESULTS OF TESTS USING TWO FLEXIBLE BRAKE-SHOES AND 11-IN. TEST-SPECIMENS

The Tests Were Made at 6 Hp. and 600 R.P.M. and Represent, for Purposes of Comparison, the Present Routine Severe-Service Test-Conditions

different from that of a lining with more saturant after test at moderate temperature.

TESTING-MACHINES IN SOME OTHER LABORATORIES

As stated previously, the original type of Bureau of Standards testing-machine, in spite of its crudeness and drawbacks, is still in regular use in a number of laboratories. In some of these cases the drum speed, the power absorption, or both, differ from that used by the Bureau. In a few cases that have come to notice this old model is used for intermittent tests or with constant brake-shoe pressure.

CARSON TYPE OF TESTING-MACHINE

In 1923, Clarence Carson, chairman of the Brake-Lining Subdivision of the S.A.E. Standards Committee, had a machine built with a view to securing certain advantages. Among these were a reduction in the time required for a durability test by the use of one small test-specimen instead of the two large ones used by the Bureau, a reduction in the drum speed, more moderate operating temperatures, and facilities for measuring the wear during running. This machine, shown in Fig. 12, has a cradled frame carrying one solid brake-shoe on its pressure-arm. The sample, 2 x 6 in. in size, is held in place by a number of pointed pegs projecting from the face of the shoe. The drum is a forged-steel web-type wheel of much heavier section than a standard passenger-car brake-drum, but is of the same diameter as the drum used by the Bureau. A number of holes in the web increase the windage. The shoe pressure and the downward force at the end of the torque-arm are measured by the spring balance and by the platform scale, respectively. It was originally proposed to operate this machine at 300 r.p.m. so that the surface speed would approximate average speeds occurring on wheel brakes of vehicles. At present, the machines of this type on which I have data are operated at 600 r.p.m. A typical test-record is shown in Fig. 13 and includes records of the coefficient of friction and the wear in inches, both plotted against time. The general shape of the upper curve, with its initial drop in the coefficient of friction soon after the beginning of the test to a very low value, is typical of all hot tests.

The type of drum used, as well as the single brake-shoe and the 3-hp. load, were adopted to reduce the operating temperature and stiffen the drum, thus minimizing distortion. In the very early stages of the work of the Bureau a heavy forged-drum was prepared; but it was discarded because the material differed from that in standard drums in general use. With the Carson machine, rings cut from brake-drums are in some cases pressed on the wheel to make tests on material identical with that of standard or special drums. This may lead to discrepancies in test results, especially at the higher temperatures. The dial-gage shown in Fig. 12 measures the change in the distance of the brake-shoe from the center of the shaft. Due to the change in drum diameter with change in temperature, this measurement does not represent the wear of the lining but rather the difference between the lining wear and the change in drum radius. This accounts for those parts of the wear curve which seem to indicate an increase in the thickness of the lining. The operating temperature prevailing in this test is understood to be around 288 deg. cent. (550 deg. fahr.). Variations in size of test-specimens used with this machine, or of the speed, as is the case in different laboratories, make comparison of results difficult. Omitting the riveting simplifies the mounting of samples

but, unless a brake-lining of the sticky type is used, the pegs in the brake-shoe will not with certainty hold the sample sufficiently to permit raising of the shoe from the drum. It is believed that the increased wear expected from the shorter test-specimen has not been found to be in proportion to the change in length of the sample. With the heavy stiff drum, which has smaller distortion under heat, less tendency to vibration and noise should be expected; but the noise is frequently somewhat disturbing, though of a different pitch than when a light drum is used.

In one laboratory one of the Carson machines is used with constant brake-shoe pressure. A change-speed gear between the motor and the machine makes it possible to operate at 525, 325 or 157 r.p.m., respectively, but tests so far have been made only with the highest of these speeds. The test-specimen used is 2 x 6 in., and most of them are ¼ in. thick. Part of a sample test-record is shown in Fig. 14. As the brake-shoe pressure is kept constant, the load and the temperature, as measured at the back of the lining, rise and fall with changes in the coefficient of friction. In the wear curve, allowance must be made for the method of measuring apparent wear, as mentioned earlier in describing this type of machine. Although the temperature prevailing during the early part of this test was not extremely high, the particular brake-lining tested showed but a slight drop in the coefficient of friction in subsequent starts, only one of which is shown on the curve. This seems to indicate that the temperature obtaining during the first continuous run of 18 hr. has a curing action on the particular saturant used.

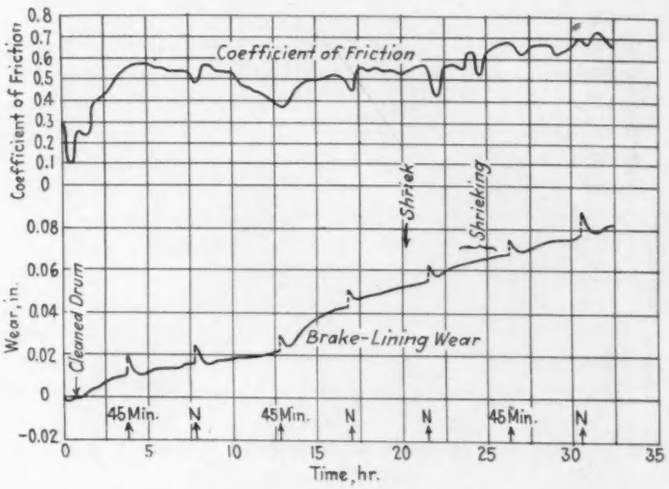


FIG. 13—TYPICAL RESULTS OF A TEST USING THE EQUIPMENT SHOWN IN FIG. 12

The Test Was Made at 3 Hp. and 600 R.P.M., the Brake-Lining Specimen Being 6⅛ In. Long, 2¼ In. Wide and 3/16 In. Thick, Having an Area of 13.8 Sq. In., and Resulted in a Power Absorption per Square Inch of Brake-Lining of 0.2174 B.Hp. The Average Wear Was 0.002585 In. per Hr. The Average Coefficient of Friction Was 0.542 and the Minimum Coefficient, 0.110. Stops Made during the Test Are Indicated by Arrows, the Length Being Given above the Arrow in Each Case. All Night Stops Are Designated by *N*

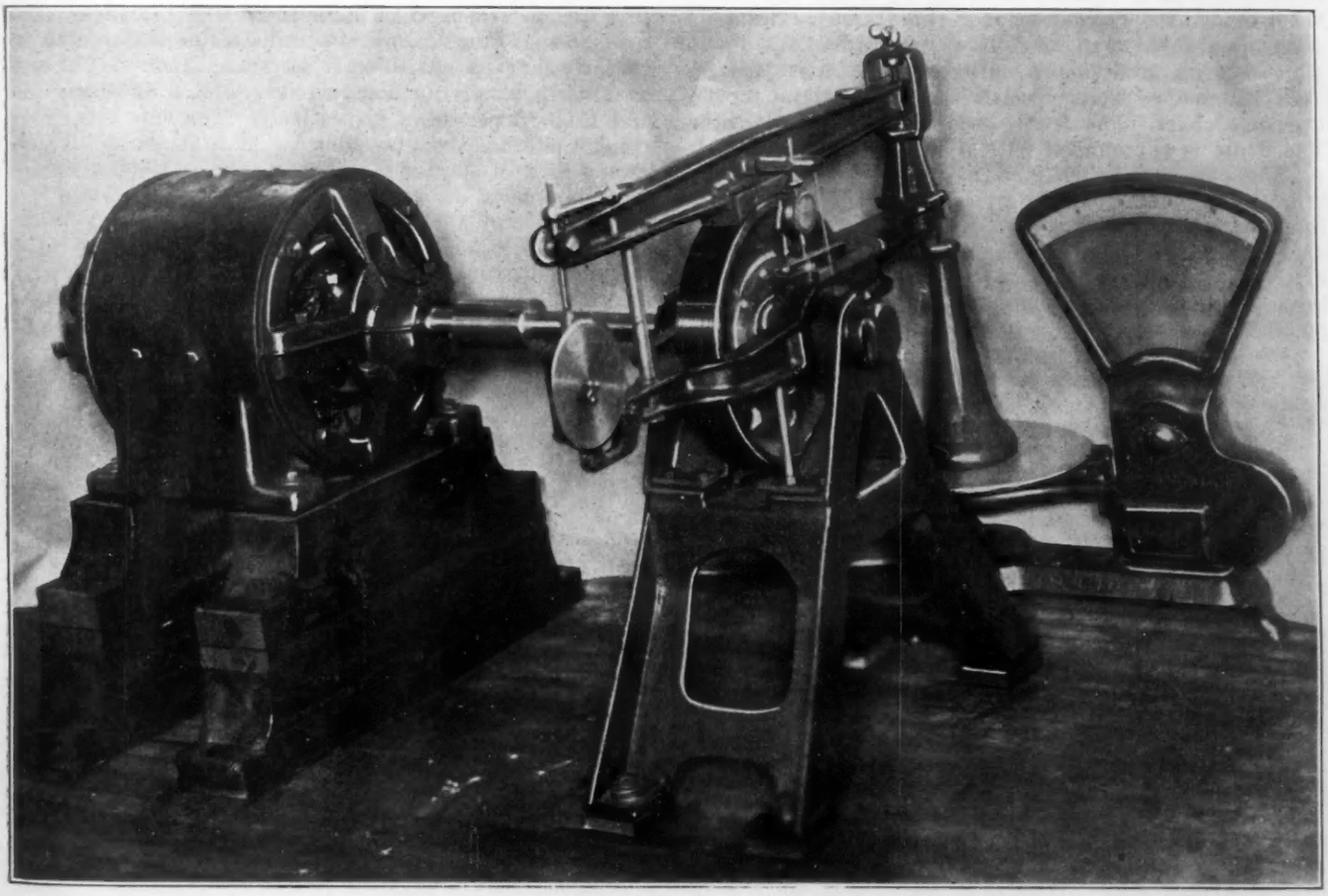


FIG. 12—CARSON TYPE OF TESTING EQUIPMENT

The Machine Has a Cradled Frame Carrying One Solid Brake-Shoe on Its Pressure-Arm. The Sample, Which Is 2 x 6 In. in Size, Is Held in Place by a Number of Pointed Pegs Projecting from the Face of the Brake-Shoe. The Drum Is a Forged-Steel Web-Type Wheel of Much Heavier Section Than a Standard Passenger-Car Brake-Drum, but Is of the Same Diameter as the Drum Used by the Bureau of Standards

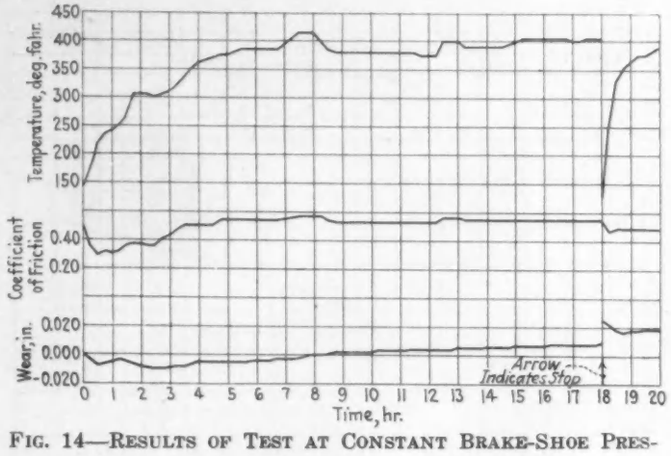


FIG. 14—RESULTS OF TEST AT CONSTANT BRAKE-SHOE PRESSURE

A Carson Testing Equipment Was Used, the Average Power Absorption Being 3.8 Hp. at 525 R.P.M. The Test-Specimen Was 6 In. Long, 2 In. Wide, and 7/32 In. Thick, Having a Density of 25.8 Grams per Cu. In. The Wear Factor Was 12.9, the Average Coefficient of Friction Was 0.541, the Minimum Coefficient 0.292, and the Average Temperature Was 409 Deg. Fahr.

STUDEBAKER TYPE OF TESTING-MACHINE

A somewhat different type of machine with brake-shoe lever carried by an oscillating cradle is used in several laboratories and is referred to as the "Studebaker" type. One of these machines is illustrated in Fig. 15. The weighted lever *I* shown at the right in the illustration is connected with a frame *J* centered by a ball-bearing on the drum-shaft. The extension of this frame carries a link with a weighted plunger *K* having an area of 1 sq. in. which works in a lapped cylinder *L* without packing. This hydraulic system records the force at the torque-arm on a chart. The drums used are 14 in. in diameter. The drum is surrounded with a shroud *M* as shown, to prevent splashing when running tests with applications of water and oil. Drums of low and of high carbon-content and of gun iron are used. The copper slide *N* shown at the right in Fig. 15, to which a thermocouple is attached, is allowed to ride on the drum behind the brake-lining and the temperature is measured by a potentiometer.

The test-specimens are 2 in. square and of 3/16-in. brake-lining and are held in a recess in the brake-shoe as shown dismantled on the table seen at the left in Fig. 15. The shoe is placed under the weighted arm *I*, and a dial-gage is arranged to measure the wear from the position of a pin in the shoe. Micrometer measurements of each test-specimen are also made before and after the test. The speed of this machine is 320 r.p.m. Tests are made with the lever weighted to give a pressure of 15, 30 or 50 lb. per sq. in. on the test-specimen. With an assumed coefficient of friction of 0.4, the power absorption would be, for the foregoing pressures, from 0.95 to 2.84 hp. Usually, the tests are run without cooling the drum.

A sample chart is shown in Fig. 16 which gives results of 1-hr. tests at each of the three foregoing unit-pressures mentioned. From a chart not reproduced, the temperature as measured by thermocouple by the method already described and with a pressure of 30 lb. per sq. in. on the brake-shoe appears to range between 120 and 150 deg. cent. (248 and 302 deg. fahr.). The apparent disadvantage of tests at constant pressure has already been commented on.

EQUIPMENT SIMULATING SERVICE CONDITIONS

The desire to submit brake-lining samples to a variety of tests in the laboratory that approximate service conditions is expressed in a machine designed to permit both continuous and intermittent tests at several speeds. This equipment is shown in Fig. 17. A small electric motor is mounted together with a change-speed gearbox in a frame arranged to oscillate on ball bearings. The pressed-steel test-drum of 14-in. diameter is mounted on the overhanging shaft-end. Tests are made at 222 and at 414 r.p.m., giving drum-surface speeds of about 800 and 1500 ft. per min., respectively. The long lever carrying the single heavily ribbed cast brake-shoe with an 11 x 2-in. test-specimen and weighted at its end as desired is applied either for constant load or is raised and lowered intermittently by a separately driven cam. Each specimen of brake-lining is first subjected to a somewhat complicated appearing schedule of various groups of intermittent applications for 5 sec. per min. at each of the speeds. This appears to be on the order of a running-

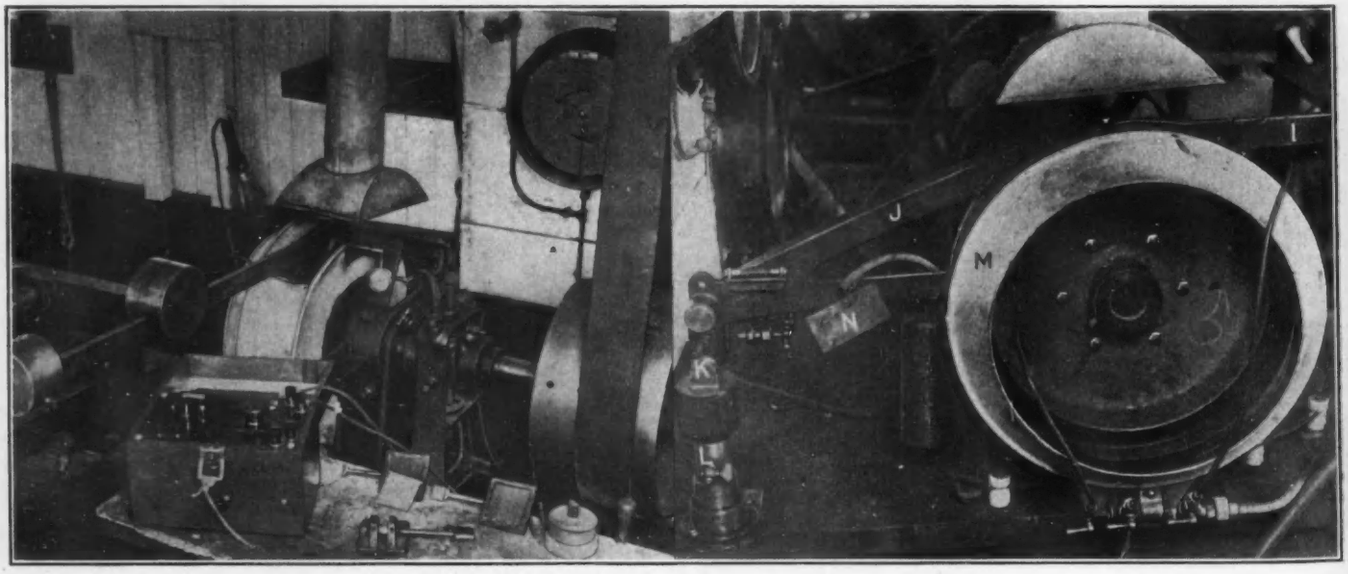


FIG. 15—STUDEBAKER TYPE OF BRAKE-LINING-TEST EQUIPMENT

The Equipment Is of Somewhat Different Type from Those Already Described in That the Brake-Shoe Lever is Carried by an Oscillating Cradle

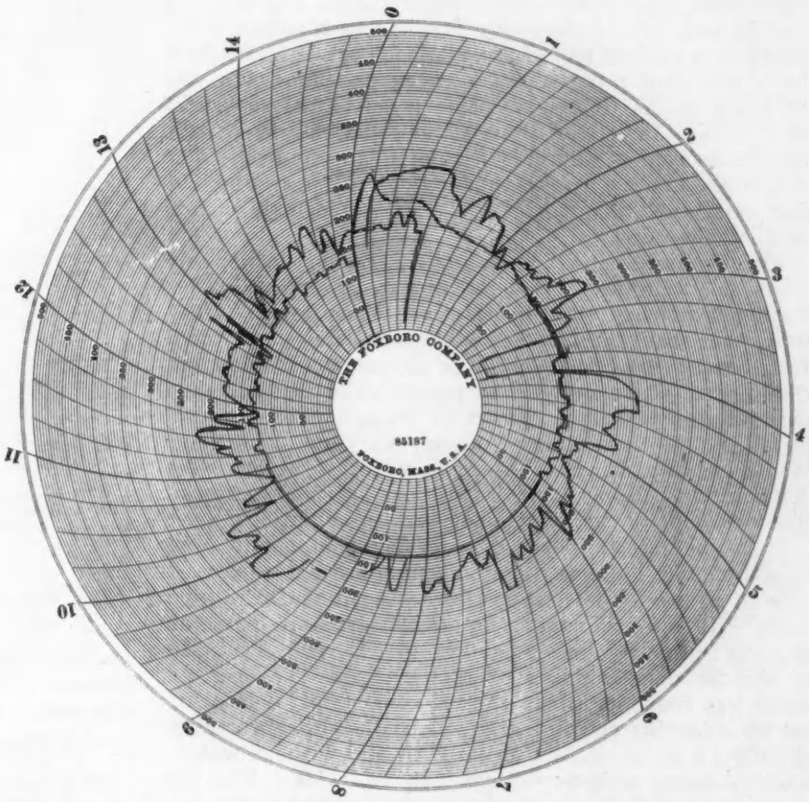


FIG. 16—TYPICAL TEST-RESULTS OBTAINED WITH THE EQUIPMENT SHOWN IN FIG. 15

The Tests Were Made with the Lever Weighted To Give a Pressure of 15, 30 and 50 Lb. Per Sq. In. on the Test-Specimen. The Curves Illustrate Three 1-Hr. Tests. The Drum Was 14 In. in Diameter, Having a Shore Hardness of 55, and the Speed Was 320 R.P.M. The Brake-Lining Specimen Was 2 In. Square and 3/16 In. Thick, the Average Wear Being 0.030 In. Per Hr. The Following Tabulation Gives the Respective Coefficients of Friction

Pressure, Lb. Per Sq. In.	Coefficient of Friction High	Low	Average
15	....	....	....
30	0.632	0.300	0.350
50	0.405	0.187	0.282

in process but, as this is done with constant pressure, brake-linings with different coefficients of friction do not fare alike. However, on account of the pressure applied, the nature of the applications and the resulting temperature, this process is not particularly severe.

These preliminary runs are followed by a group of

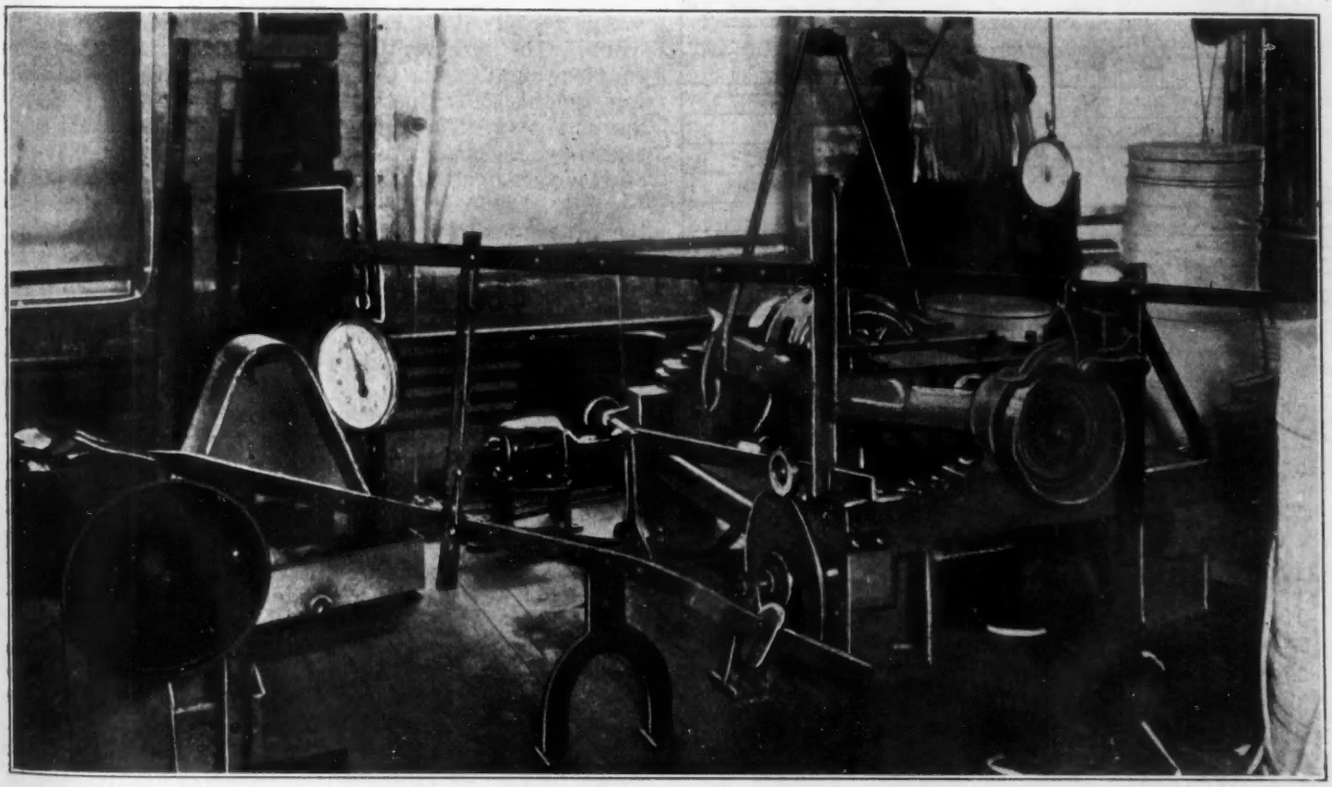


FIG. 17—EQUIPMENT FOR CONTINUOUS AND FOR INTERMITTENT TESTS

The Desire To Submit Brake-Lining Samples to a Variety of Tests in the Laboratory That Approximate Service Conditions Led to the Design of the Equipment Shown

four tests with intermittent applications, 1½ min. on and ½ min. off, as shown in Fig. 18; each series is followed by a cooling period of 15 min. Part or all of these tests are then repeated as a check on changes in the behavior of the lining, particularly as to the coefficient of friction. In each of these latter constant-power tests, the brake-shoe pressure is regulated as required. The maximum temperature is understood to be around 205 deg. cent. (401 deg. fahr.), and that applies only during part of the runs.

The changes in the coefficient of friction which are found in such a test as is shown in Fig. 18 for two linings appear somewhat remarkable at first inspection. However, that many of these changes may occur is evident from a study of results obtained in our work, including that presented in my earlier paper. The test schedule used in this case is an effort to bring out the characteristics of brake-linings under varying conditions. While open to criticism in some ways, it nevertheless demonstrates clearly what erratic changes may occur in the coefficient of friction under certain conditions.

It is understood that a few testing equipments used by automobile builders employ a standard external-band type of brake for laboratory tests. A simple band-type brake with 180 deg. contact on a drum of 12-in. diameter as used in one instance is shown in Fig. 19. In spite of obvious disadvantages of this machine, the user no doubt has found it a help if used consistently. Most of the tests on this machine are made with 3-hp. absorption at 1150 r.p.m. on a 12-in. drum with and without water-cooling, using a test-specimen 1½ in. wide. Fig. 20 shows the result of a test with a water-cooled drum and

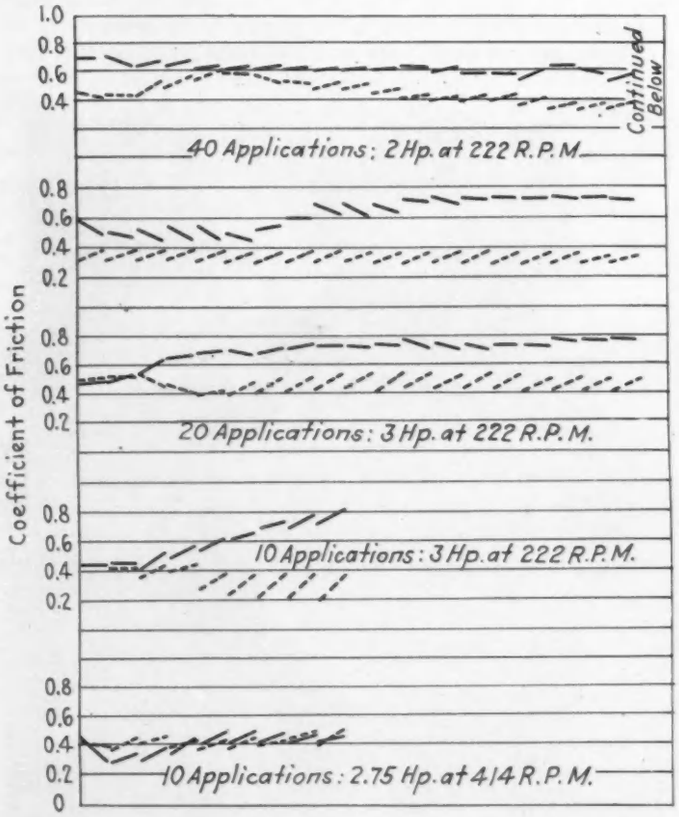


FIG. 18—RESULTS OF INTERMITTENT TESTS WITH EQUIPMENT SHOWN IN FIG. 17

The Preliminary Tests Were Followed by a Group of Four Tests with Intermittent Applications, 1½ Min. "On" and ½ Min. "Off," as Shown. Each Series Was Followed by a Cooling Period of 15 Min.

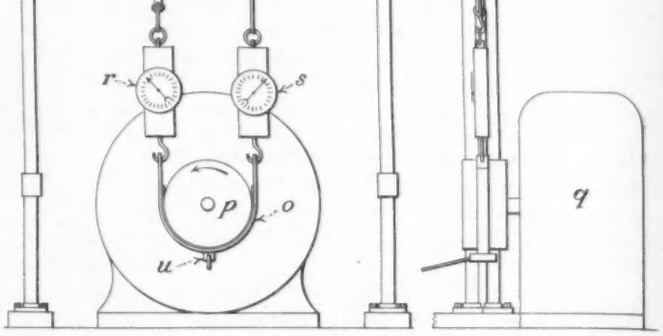


FIG. 19—APPARATUS FOR DETERMINING THE COEFFICIENT OF FRICTION OF BRAKE-LINING

A Simple Band-Type Brake *o* Is Shown, Having 180-Deg. Contact with a Drum *p* of 12-In. Diameter Mounted on the Shaft of Motor *q*. The Sample of Brake-Lining Is Fastened to a Flexible Steel-Band by Four Rivets, and the Tension of the Band Is Measured by the Two Spring-Scales Shown at *r* and *s*. The Pressure on the Sample of Brake-Lining Can be Varied by the Handwheel *t*. The Temperature at the Under Side of the Brake-Lining Is Determined from a Thermometer the Bulb of Which Is Inserted in the Block Shown at *u*

we find the characteristics expected; that is, slight changes in the coefficient of friction, including an initial rise, and a fairly uniform rate of loss in thickness.

FOREIGN BRAKE-LINING TESTING-EQUIPMENT

Those studying brake-linings abroad are experiencing similar difficulties, and it is therefore of interest to give the information available on some of the equipment and test methods employed in two foreign laboratories. In one case the equipment is of the type shown diagrammatically in Fig. 21. The weighted beam carrying the brake-shoe is pivoted on a substantial stand with provision for leveling the beam for various diameters of drum. The screw adjustment for the brake-shoe, the counterweight of the beam and the weight-pan and sliding weight for adjustment of the brake-shoe pressure are as shown. The drum is mounted on the shaft of a cradle-dynamometer. A hollow steel drum, of 0.40-per cent carbon-steel, is used at a surface speed of 1000 ft. per min. The 5 x 2 x ¼-in. test-specimen is fastened to the brake-shoe by one central rivet. The front end of the specimen also rests against two small tapered pegs fixed in the brake-shoe. For measuring the temperature during the tests, a thermocouple is secured in the brake-shoe end of the rivet used. Any enlargement occurring in the rivet hole is used as a gage of the rivet-holding ability of the material.

Tests are made under conditions covering a wide range, with either the pressure or the power absorption per square inch held constant during a given test, both with water-cooled and with uncooled drums. It is understood that the constant-pressure test is found satisfactory for checking the uniformity of this manufacturer's standard product. Comparisons of different materials, including the products of others, are made with constant power-absorption of 10 hp. at 1000 ft. per min. and with a specimen ¼ in. thick having an area of 10 sq. in. The temperature on this equipment with uncooled drums reaches from 275 to 300 deg. cent. (527 to 572 deg. fahr.) at the rivet in 1 hr. The test is made in periods of 1 hr. followed by intervals for cooling. A sample curve-sheet shown in Fig. 22 indicates that some of the periods in this case were less than 1 hr., possibly to prevent a temperature rise beyond the figure of 527 deg. fahr. shown

in the record. Limiting the temperature to the figures given is no doubt connected in a way with the behavior of this manufacturer's brake-lining. It is of interest to note that the life of this lining at 302 deg. fahr. is said to be twice that at about 527 deg. fahr., with the same velocity and pressure in both cases. Fig. 22, which shows

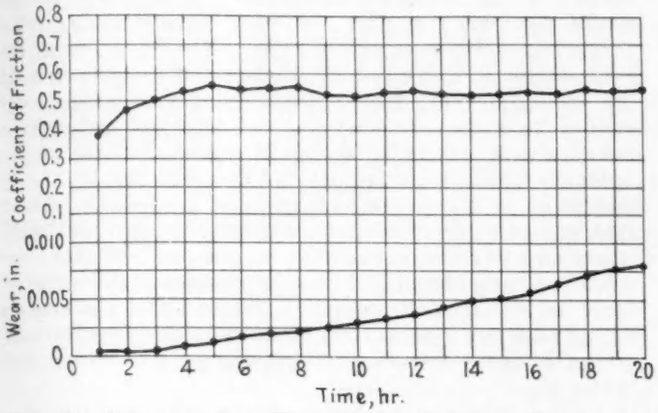


FIG. 20—RESULTS OF A TEST MADE WITH THE EQUIPMENT SHOWN IN FIG. 19

The Drum Was Water-Cooled and the Power Absorption Was 3 Hp. at 1150 R.P.M. The Test-Specimen Was 1½ In. Wide

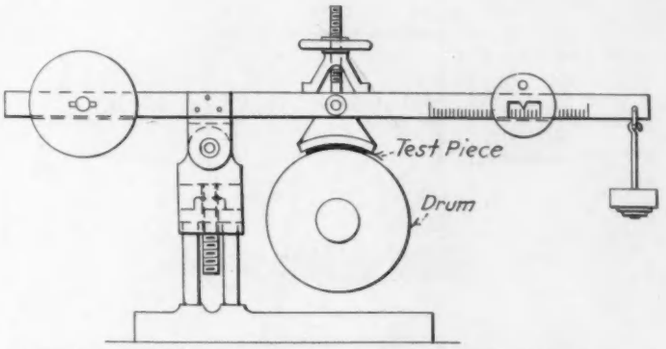


FIG. 21—BRAKE-LINING TESTING-EQUIPMENT USED BY A EUROPEAN MANUFACTURER

the results of a test of three samples of a competitor's lining under the foregoing conditions, is of interest in showing the various items recorded for comparison. These include the weight loss, the loss in thickness, the relation between these two, the horsepower-hours per gram lost and the coefficient of friction. These values are shown for each hour singly, averaged for each test-specimen, and for all together. The grand average life in horsepower-hours calculated for ¼-in. thickness is

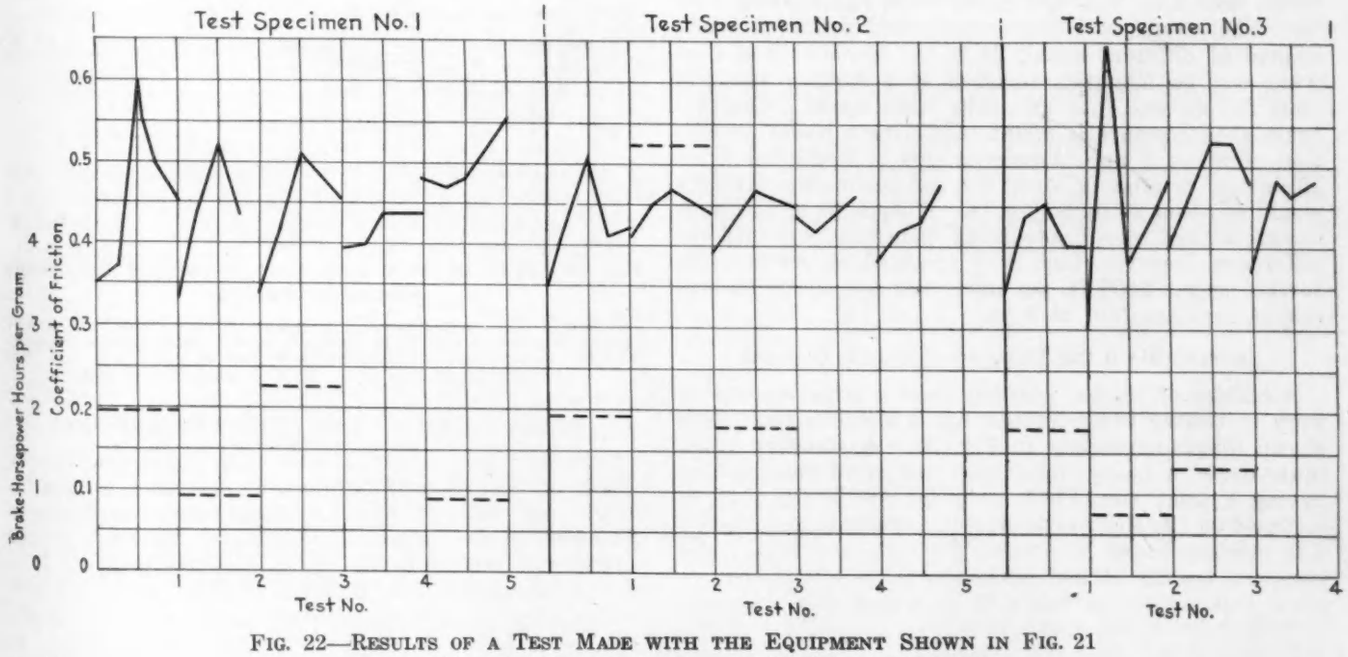


FIG. 22—RESULTS OF A TEST MADE WITH THE EQUIPMENT SHOWN IN FIG. 21

Details of the Data Obtained Are Given in the Following Tabulation

Details	Test-Specimen 1	2	3
Original Weight, grams	65.70	65.85	65.22
65.59 Grams = Average Weight)			
Original Thickness, In.	0.240	0.241	0.240
Excess Loss, per cent, (Thickness ÷ Weight)	—10.3	—28.2	—17.0
Average Power-Absorption, (b.hp. per gram × hr.)	1.258	2.382	1.100
Average Coefficient of Friction	0.455	0.438	0.446
Average Power-Absorption, b.hp. per hr. per gram	82.5	156.0	72.0

Test-Specimen	Test No.	Loss Each Hour Weight, Grams	Thickness, In.
1	1	5.17	0.003
	2	11.07	0.032
	3	4.48	0.023
	4	...	...
	5	11.08	0.046
2	1	5.09	0.003
	2	1.91	0.009
	3	5.60	0.021
	4	...	...
	5	...	...
3	1	5.60	0.002
	2	14.12	0.047
	3	7.64	0.034
	4	...	...
	5	...	...
	Total Loss	71.76	...

Test-Specimen 5 In. Long, 2 In. wide and ¼ In. Thick; Area, 10 Sq. In. Successive 1-Hr. Tests. Power Absorption 10 Hp. at 1000 Ft. per Min. The Temperature Rise Each Hour Was from 70 to 520 Deg. Fahr. The Following Values Represent an Average of the Results Obtained from the Three Test-Specimens: Coefficient of Friction, 0.447; B.Hp. per Hr. per Gram, 1.395; Length of Life in B.Hp-Hr. Calculated for ¼-In. Thickness, 91.4; Efficiency Value, 40.8 Per Cent. The Dash Lines in the Chart Show the Brake-Horsepower Hours per Gram for Each of the 1-Hr. Tests for Which They Are Shown. The Solid Lines Show the Coefficients of Friction

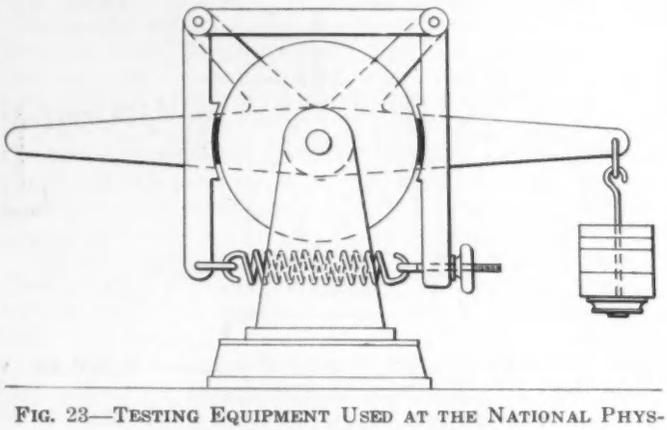


FIG. 23—TESTING EQUIPMENT USED AT THE NATIONAL PHYSICAL LABORATORY, ENGLAND

given and, finally, an average efficiency value, 40.8 per cent, the basis for which is not apparent.

It is understood that the National Physical Laboratory, England, uses test equipment such as is shown diagrammatically in Fig. 23. An oscillating cradle weighted as indicated carries two arms, each with two brake-shoes. These shoes carry test-specimens arranged side-by-side on the drum. There is a total of four specimens, each 3 in. long and ¾ in. wide, aggregating 9 sq. in. The strong cast-iron water-cooled drum on which sleeves of different metal, 24 in. in diameter and 4 in. wide, can be mounted, revolves at a surface speed of 4000 ft. per min., an unusually high speed. Constant brake-shoe pressure is maintained with a power absorption of about 9 hp. Assuming this to apply for a coefficient of friction of about 0.4, the brake-shoe pressure would be about 20 lb. per sq. in. A machine of the same design is used by a brake-lining manufacturer, with the difference, however, that it is operated at one-half the surface speed, 2000 ft. per min., and the power absorption is kept constant at 9 hp.

TESTING-MACHINE USED BY A TRUCK BUILDER

A builder of trucks, who has done a large amount of work in testing brake-linings, has a machine such as is shown diagrammatically in Fig. 24. A standard truck brake-drum, a heavy well-ribbed and rigid steel-casting having a thick rim, 11-in. diameter and 6 in. wide, is mounted on the shaft extension of a cradle dynamometer. The surface speed is around 2100 ft. per min. The standard heavily ribbed brake-shoes are mounted on a stand and are counterbalanced by means of a weighted lever connecting the open free ends. The two test-specimens, each of 2-sq. in. area, are riveted to steel plates which are slipped into recesses cut in the face of the brake-shoes.

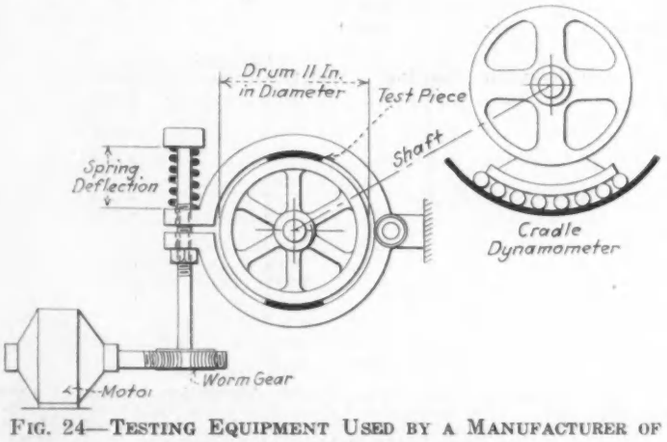


FIG. 24—TESTING EQUIPMENT USED BY A MANUFACTURER OF MOTOR-TRUCKS

Tests are made with a power absorption of 5 hp., the tension on the adjusting stud being regulated by the electric motor actuated from the weight beam of the cradle dynanometer and revolving the adjusting stud through a worm-gear as indicated. The pressure on the brake-shoes is measured by gaging the compression on the spring shown. The test results in general are very similar to those obtained on any machine under high temperatures, as shown in Fig. 25. In view of the known influence of various factors on the test results, as to coefficient of friction and as to wear, it is small wonder that considerable difficulty is experienced in correlating laboratory results with field experiences in this case when it is considered that, in the vehicles manufactured, there is a very wide range in the braking systems as regards surface speeds, unit pressures, design of drums, design of shoes, the location and exposure of drums and in the drum materials used.

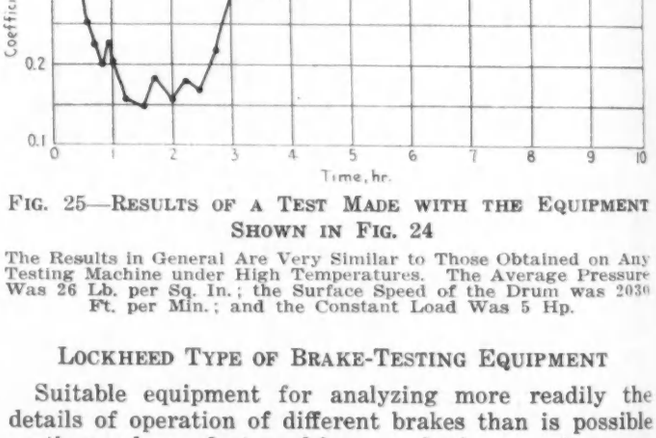


FIG. 25—RESULTS OF A TEST MADE WITH THE EQUIPMENT SHOWN IN FIG. 24

The Results in General Are Very Similar to Those Obtained on Any Testing Machine under High Temperatures. The Average Pressure Was 26 Lb. per Sq. In.; the Surface Speed of the Drum was 2030 Ft. per Min.; and the Constant Load Was 5 Hp.

LOCKHEED TYPE OF BRAKE-TESTING EQUIPMENT

Suitable equipment for analyzing more readily the details of operation of different brakes than is possible on the road was first used by some brake manufacturers not only for such studies but also for ascertaining the behavior of various brake-linings on their brakes. It is referred to as the Lockheed type of brake tester. A few brake-lining manufacturers have installed such equipment recently to test the adaptability of their linings to any particular type of brake and to assist them in modifying their product suitably, if necessary. While primarily a brake-testing equipment, it can be adapted for tests of brake-lining materials as such, in either continuous or intermittent operation.

The Lockheed type of brake-testing equipment consists of an electric motor of about 40 to 50 hp. connected by a chain drive to a shaft carrying a flywheel and a brake-drum. The brake-shoes, and the mounting and operating mechanism, as used in the vehicle, are suitably installed so as to oscillate and are provided with a torque-arm, the outer end of which rests on a platform scale which indicates the torque, while an interposed sylphon and connected dial-recorder registers the force. Means are provided for applying the brakes intermittently with a definite pressure.

In a machine of this type, as seen in the laboratory of

a brake-lining manufacturer, an hydraulic brake was in use and was applied by means of an air-valve intermittently actuated through a speed-reducing drive from the drum-shaft, and raising or releasing a weight operating the master-cylinder of the brake-system. The equipment can, of course, be adapted for other types of brake. A standard Lockheed internal-type brake with 14-in. drum of unknown analysis was used. The pressure used in the hydraulic system was kept constant at 300 lb. per sq. in. and the drum-speed was 218 r.p.m. The brake-lining consisted of two pieces each 14⅞ x 1¾ x 3/16 in. The application interval was 4¼ min., the application itself covering about 5 sec. A sample record is shown in Fig. 26. The test is continued for 48 hr. or more. The temperature reached is reported as estimated at 175 to 190 deg. cent. (347 to 374 deg. fahr.). The power absorption, as well as comparative values of the coefficient of friction and its changes during this test, can be ascertained from the record. The chart shown refers to the last 11 hr. of a 50 or 60-hr. test during the first part of which there were variations in the record to an extent not appearing in the chart. However, the changes were not very large for this lining compared with some other results seen.

The foregoing machine was being used solely for a study of the coefficient of friction. While it should be satisfactory for this use if test conditions are suitably selected, it is extremely doubtful whether any advantage is being obtained in this case commensurate with the amount of machinery in use. It will be noted that the full force is applied only a very short part of the time, this being evidenced further by the slow travel of the pen to the maximum position. As the movement of the dial is so slow that the pen draws but one line, no record is had of whether changes in the coefficient of friction occur during these short applications. This equipment is capable of being used to better advantage,

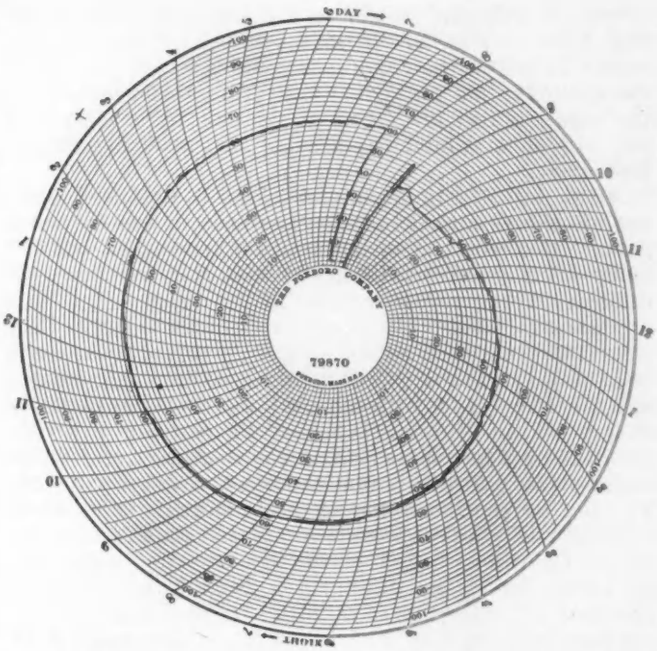


FIG. 27—TEST RECORD FROM A "CONSTANT-PRESSURE" TESTING MACHINE

The Original Coefficient of Friction Was 0.185 and Became 0.158 at the Finish. The Wear Was 0.00117 In. per Hr.

and no doubt in time will be suitably adapted and so used.

For wear tests and for studying the effect of water and oil, this laboratory uses a constant-pressure machine similar to that already described as the Studebaker type. Tests are made at a pressure of only 15 lb. per sq. in. on the lining and at a drum speed of 300 r.p.m. Tempera-

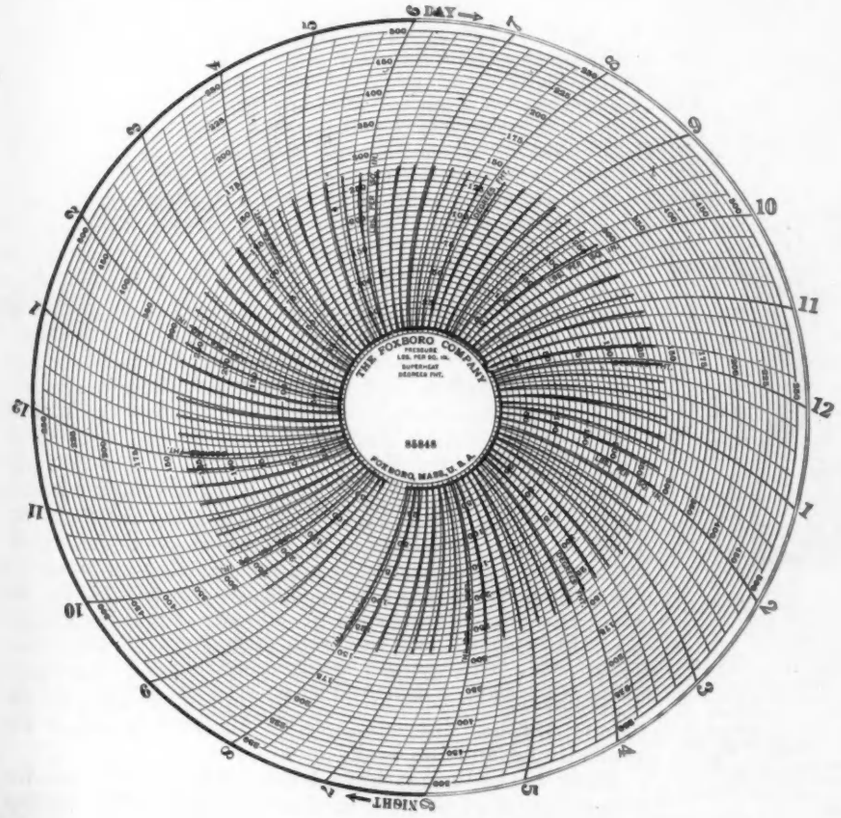


FIG. 26—TEST RECORD FROM "LOCKHEED" TYPE OF TESTING EQUIPMENT

The Complete Lockheed Mechanism Was Used, the Torque-Arm Being 31½ In. in. Length, and the Temperature 347 to 374 Deg. Fahr.

tures are estimated at 107 to 120 deg. cent. (225 to 248 deg. fahr.). Fig. 27 shows the result of one of these tests. It is evident from specimens taken from both of the foregoing machines that the tests are not severe and the temperatures low. One of the original machines of the Bureau of Standards type is also available in this laboratory.

At the left of Fig. 28, a view taken in another laboratory, is shown a machine that has been in use for many years. It consists of an internally water-cooled cylinder made of rings about 10 in. in diameter, composed of different metals, which rotates at 316 r.p.m. The tests are usually made on 0.25-per cent carbon-steel. The weighted beam seen raised in the photograph carries a solid shoe, and a 6½ x 2-in. brake-lining specimen is applied to the drum with a constant pressure of about 34 lb. per sq. in. Power input of the driving motor is recorded by a wattmeter. With the coefficient of friction assumed at 0.4, the power absorbed would be 4.4 hp. The test is continued for 12 hr. and the coefficient of friction and power absorption are calculated from the wattmeter record. The percentage loss in weight and the horsepower-hours computed to wear ¼-in. thickness are used as criteria of durability. The changes in the coefficient are in line with what might be expected at the temperatures resulting from the water-cooling. Fig. 29 shows the behavior on this machine in comparison with that on a machine of the original Bureau of Standards type also used in this laboratory, both tests applying to the same brake-lining material. This same laboratory also has installed recently a machine, shown in Fig. 30, on which any type of brake can be mounted. The flywheel and operating speed are designed to simulate a 3000-lb. car traveling at 30 m.p.h. The brake-lever is operated by air under variable pressure. Arrangements for full automatic control are being made.

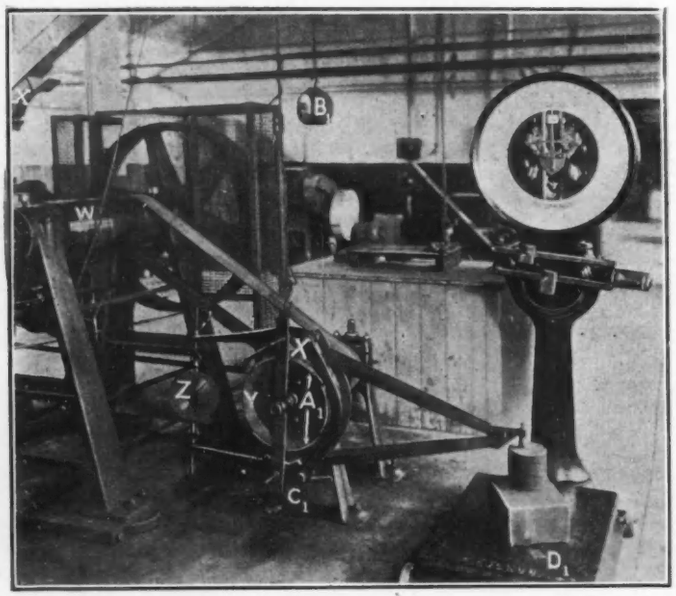


FIG. 28—TESTING EQUIPMENT PROVIDED WITH A WATER-COOLED CYLINDER

The Machine at the Left Comprises an Internally Water-Cooled Cylinder *W* Made of Rings of Different Metals about 10 In. in Diameter Which Rotates at 316 R.P.M. The Weighted Beam *Y* Carries a Solid Brake-Shoe *X* and the Brake-Lining Specimen Is Applied to the 15-In. Drum *Y* with a Constant Pressure of about 34 Lb. per Sq. In. The Dial Scale *Z* Records the Brake-Band Pressure, and the Brake-Bands Indicated at A_1 Are 11 In. Long, 2 In. Wide and 3/16 In. Thick. At B_1 Is Shown the Counterweight for the Bureau of Standards Machine Located at C_1, the Arm of Which Bears on the Platform Scale at D_1

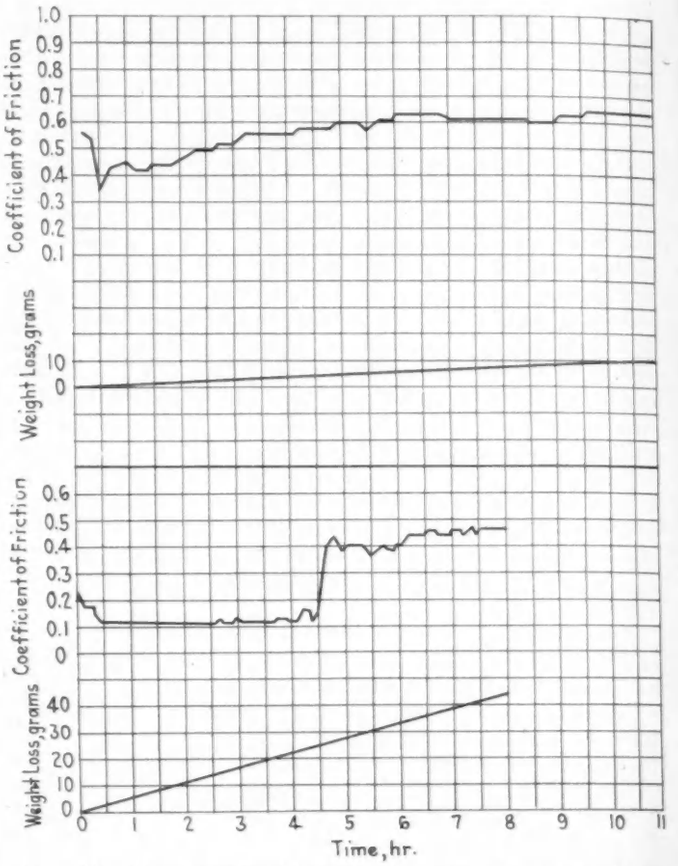


FIG. 29—COMPARATIVE RESULTS OBTAINED WITH THE TESTING EQUIPMENT SHOWN IN FIG. 28

The Curve Shown in the Upper Portion Was Obtained on the Cold-Drum Machine. The 10-In. Drum Was Water-Cooled and Its Speed Was 316 R.P.M. One Specimen of Brake-Lining 6½ In. Long, 2 In. Wide and 3/16 In. Thick Was Tested, the Pressure Being 33.8 Lb. per Sq. In. The Loss in Weight Was 11 Grams, or 16.15 Per Cent. The Power Absorption Was 75.6 B.Hp-Hr. in 12 Hr. To Wear the Sample ¼ In. Would Require 625 B.Hp-Hr. The Curve Shown in the Lower Portion Was Made on the Old-Type Bureau of Standards Machine, and the 14-In. Drum Was Not Cooled. Two Specimens Were Tested, Each Being 11 In. Long, 2 In. Wide and 3/16 In. Thick, and the Speed Was 380 R.P.M. The Power Absorption Was 3.7 B.Hp. per Hr. for 8 Hr., or 29.6 B.Hp-Hr. The Weight Loss Was 48 Grams, or 21.8 Per Cent., and 180.5 B.Hp-Hr. Would Be Required To Wear the Sample ¼ In.

Fig. 31 shows another such brake-testing machine recently put into use by a brake manufacturer who is developing a new type of brake and who uses the machine in this work and also to determine what brake-linings are best suited for his requirements. The motor shaft carries at its rear end a large hub to which one of several flywheel rims of different size and weight can be attached. A chain drive connects to the drum-shaft, which has ample room between the bearings for mounting the drum of any kind of brake. The large platform-scale at the left supports the adjustable torque-arm connected with the brake-shoe system, while the springless scale suspended from the ceiling measures the force applied at the brake-lever. Provision is made for measuring the speed, and for indicating the number of revolutions to stop after application of the brake, deceleration and other items of interest. The drum temperature is measured by a thermocouple held in close proximity to the drum surface in the recess of a shield of insulating material which is allowed to rest on the drum; another thermocouple is inserted between the brake-lining and the brake-shoe.

Many brake-linings have been tested recently on the foregoing machine in continuous tests with various

brake-shoe pressures. The two charts shown in Fig. 32 are of interest because they afford a good illustration of the many changes occurring in the linings tested, how these changes, through change in the power absorption, affect the temperature, and that these changes do not follow entirely the temperature changes as measured, even with different pieces of the same lining.

Some other machines are in use that differ but slightly in dimensions or arrangement from those described. There may also be some other types possessing interesting features of which I have no knowledge or particulars. If this summary leads to particulars of any such machines being added to the record together with details of interesting test results, such information may assist in the further development of test methods; provided, of course, that it includes the fullest possible account of all conditions affecting the results.

A Review of Results

In reviewing the results of the test methods and equipment described, including the information presented in the earlier paper, we find a general uniformity of results if allowances for test conditions are made. The coefficient of friction of brake-lining materials in general use is affected very materially by such influences as heat and the presence of water and oil. At such comparatively low temperatures as prevail in tests with water-cooled drums, the changes in coefficient of friction are relatively small and the values may be higher than at room temperature. The changes at higher temperatures are greater and show in particular a drop in the coefficient which is undesirable in the service for which these materials are used. Still further increases in temperature cause more or less destructive effects which begin at the surface and, with prolonged action or further increase, lead to a more or less marked impairment of the structure and its mechanical strength and increase the capacity of the linings to absorb water and oil.

Due to the rapid progress of the destructive effect on the surface material during the early part of tests, leading to very high temperatures, the coefficient of friction may not drop to the extreme low values shown at less destructive temperatures. Except for this feature, however, the changes in the coefficient of friction in the undesired downward direction is clearly demonstrated in the severest tests in regular use.

Brake-linings of the types and materials in general use in automotive work, within both the range of temperature not destructive to their nature and well beyond the point where high temperature causes marked changes in their components, seem to show that neither pressure nor surface speed alone or combined has any marked or objectionable influence on the coefficient of friction;

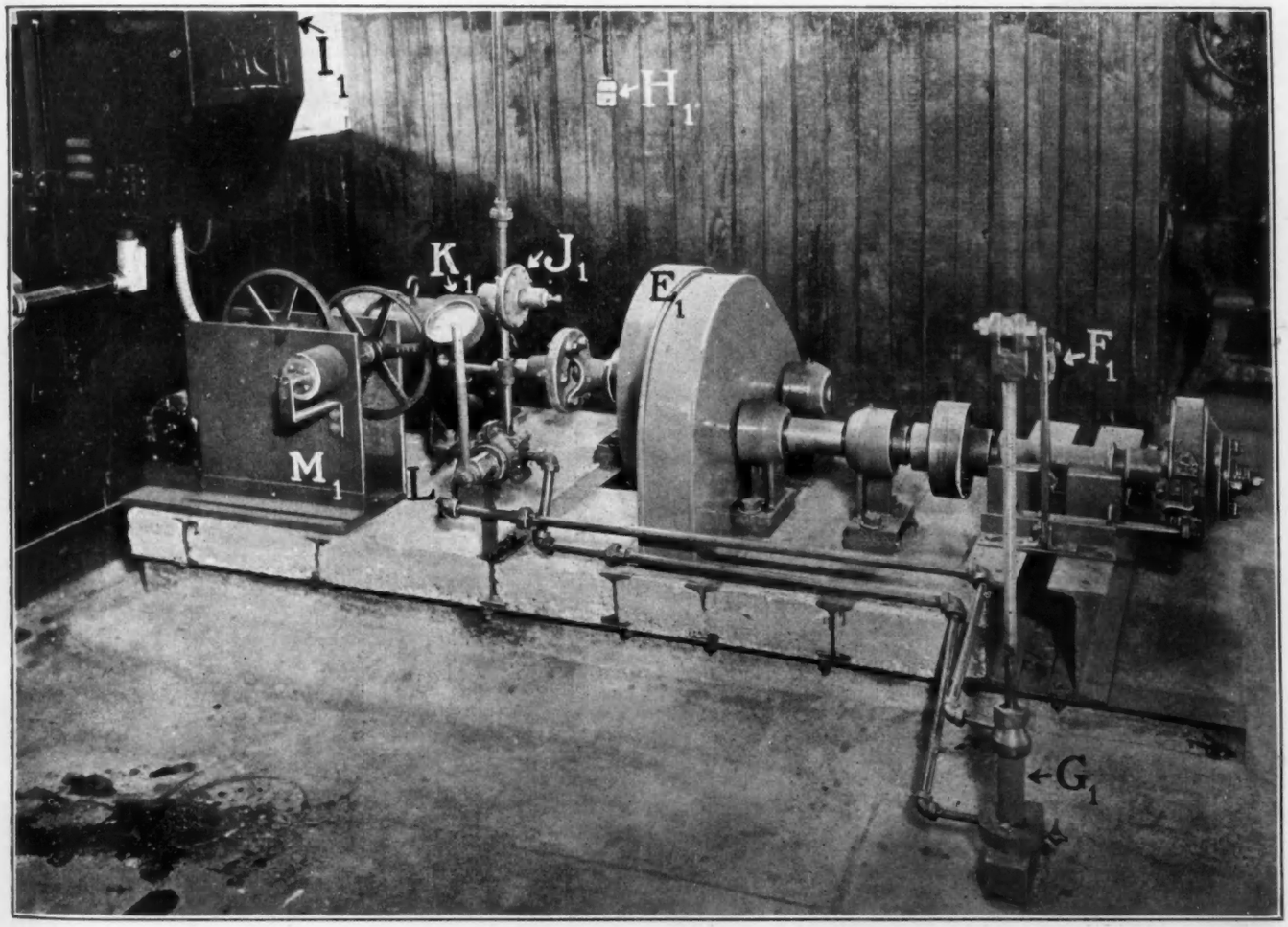


Fig. 30—Testing Equipment on Which Any Type of Brake Can Be Mounted

The Flywheel E_1 and the Operating Speed Are Designed So As To Simulate a 3000-Lb. Car Traveling at 30 M.P.H. The Brake-Lever System F_1 Is Operated by Air under Variable Pressure from the Air Cylinder Shown at G_1. Other Main Features of the Equipment Are the Hand Control-Switch at H_1, the Automatic Starting Box at I_1, the Air-Pressure Regulator at J_1, the Gage at K_1, the Hand Air-Brake-Control Lever at L_1, and the Automatic Control-Equipment at M_1

but rather that the changes in the latter are for practical purposes due entirely to the influence of heat.

The access of water and oil to the braking surface should be prevented so far as possible, because both may cause changes in the coefficient of friction closely similar to those resulting from high temperatures. This loss can, however, be recovered in proportion to the heat generated by applications of the brakes. After access of oil and such application of heat beyond a certain point, the coefficient of friction may indeed reach higher values than before the presence of the oil, an effect probably due to carbonizing of the oil and possibly to the combination of oil with other foreign matter present.

With brake-linings of the types and materials now in general use, the minimum values of the coefficient of friction resulting from the increased temperature—and the same applies to water and oil—seem to be closely similar, whether the value under normal or favorable conditions is high or low. The possible variation is therefore the more marked and more objectionable in linings with a normally high coefficient of friction. A high coefficient, whether normal or resulting only under certain conditions of operation, has the further objection that it increases the tendency to harshness, grabbing and locking, and noise, resulting from compromises in brake design, lack of rigidity in drums and other parts and from similar causes connected with the brake and chassis rather than with the brake-lining itself. These considerations appear to indicate that linings with a moderate coefficient of friction under normal conditions offer advantages whenever the frictional characteristics are similar to those of the linings now used. With a material so important from a safety standpoint, the first consideration should be utmost reliability and uniformity under all conditions.

The recently increased demand for brake-linings having greater uniformity of coefficient of friction has led to renewed efforts to produce such material. Claims are made of results achieved in this direction especially as concerns the influence of heat but partly also that of water. Such claims have been made from time to time since the early tests showed the variations in frictional characteristics; but they have not been, or have been only to a slight extent, substantiated by any material so far investigated by us. Therefore some skepticism is perhaps permitted, especially when several of the materials for which such claims are now made show far less uniformity when tested by other manufacturers, who sometimes make similar claims for their own latest products. The explanation of these discrepancies may be found in differences in the test methods and because most of the test procedures cover too narrow a range.

Asbestos, as the result of its heat-resisting qualities, forms the basis of most present linings; but, for well-known reasons, it is combined with other materials having less heat-resistance. As the combination is also less heat-resistant, it does not permit the utilization of the qualities of the asbestos to their full extent. Tests show that some of these other materials at least contribute largely to, if they do not entirely cause, the lowering of the coefficient of friction. The materials added do not reduce the magnitude of changes in the coefficient of friction but, rather, they increase it.

In some other tests the rate of wear at high temperatures has also been found to be lowered by a reduction in the amount of these less heat-resistant materials or

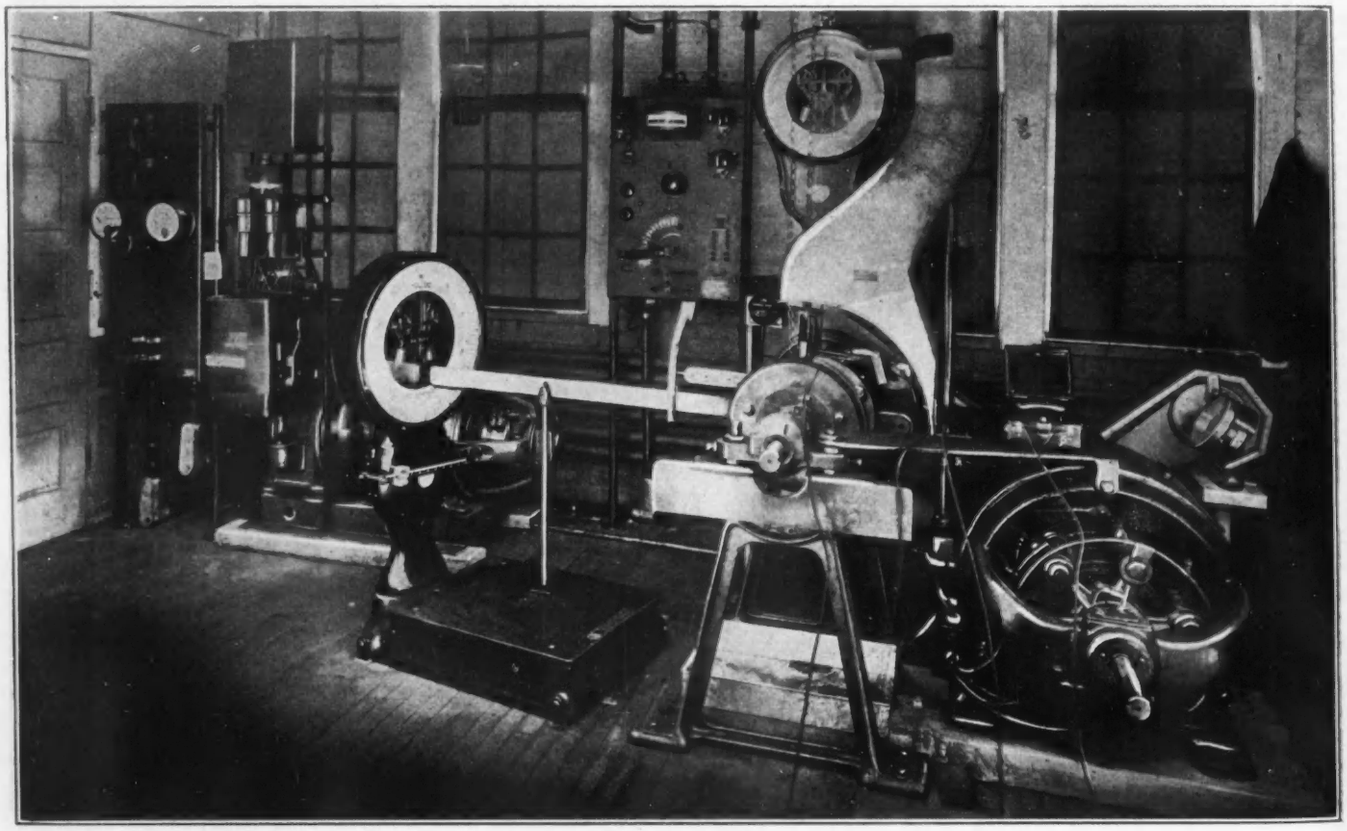


FIG. 31—ANOTHER TYPE OF BRAKE-TESTING MACHINE

This Machine Is Used by a Brake Manufacturer Who Is Developing a New Type of Brake. He Uses It Also To Determine What Brake-Linings Are Best Suited for His Requirements

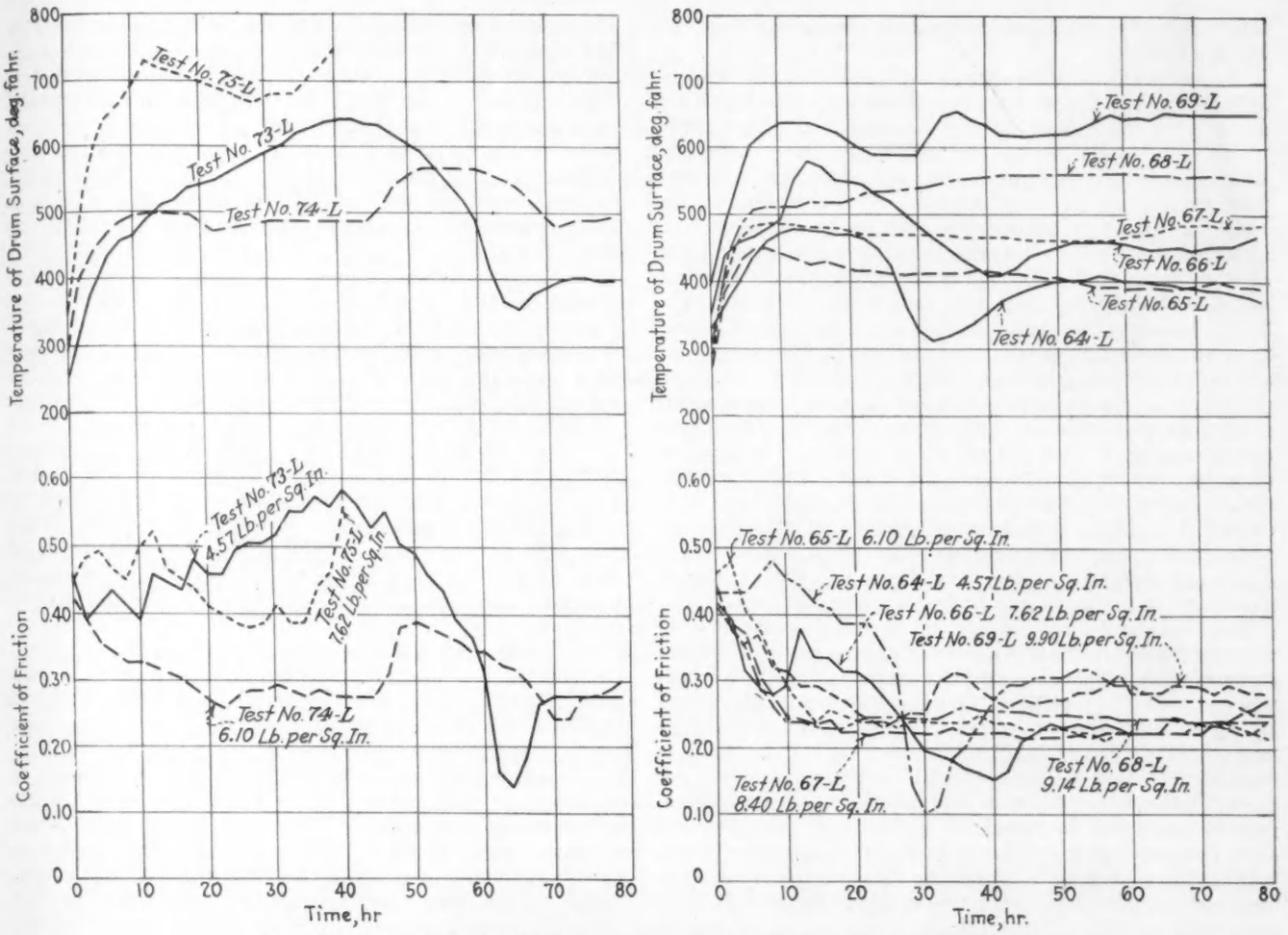

Temperature of Drum Surface, deg. fahr.
Test No. 75-L
Test No. 73-L
Test No. 74-L
Coefficient of Friction
Test No. 73-L 4.57 Lb. per Sq. In.
Test No. 75-L 7.62 Lb. per Sq. In.
Test No. 74-L 6.10 Lb. per Sq. In.
Time, hr
Temperature of Drum Surface, deg. fahr.
Test No. 69-L
Test No. 68-L
Test No. 67-L
Test No. 66-L
Test No. 65-L
Test No. 64-L
Coefficient of Friction
Test No. 65-L 6.10 Lb. per Sq. In.
Test No. 64-L 4.57 Lb. per Sq. In.
Test No. 66-L 7.62 Lb. per Sq. In.
Test No. 69-L 9.90 Lb. per Sq. In.
Test No. 68-L 9.14 Lb. per Sq. In.
Test No. 67-L 8.40 Lb. per Sq. In.
Time, hr.

FIG. 32—TEST RECORDS OBTAINED WITH THE EQUIPMENT SHOWN IN FIG. 31

The Charts Illustrate the Many Changes Occurring in the Brake-Linings Tested; How These Changes, Through Changes in the Power Absorption, Affect the Temperature; and That the Changes Do Not Follow Entirely the Temperature Changes As Measured, Even with Different Pieces of the Same Lining. The Curves at the Left Are for One Lining and Those at the Right Are for Another

their omission. While for other reasons the omission of the saturant in present brake-linings is not feasible, these data indicate that the asbestos is placed at a disadvantage by the other constituents. It is therefore preferable to use in the composition, if possible, only materials which will admit the full utilization of the qualities of asbestos or which, in combination with asbestos, will have even superior qualities.

Intermittent tests may give information of value in the testing of brake-linings. The wear of linings may possibly differ under alternate application and release from that shown in continuous application; just as in abrasion tests made with metal discs, for instance, it has been found that the wear was reduced materially if the abraded material was removed. In view of the influences occurring in actual service it is doubtful, however, whether such additional data as may be found will be of material value.

The test equipments designed especially for tests of brake mechanisms should prove useful for ascertaining and perhaps correcting any special conditions which the various brake designs impose upon the lining. However, more information might be gained with such machines from a repetition of actual stops rather than repeated applications of insufficient intensity to retard more than slightly the speed of the drum and the flywheel. Much of the work done now with these machines can, it is believed, be done equally as well with less equipment and without the loss of time entailed by light applications for periods constituting only a very small percentage of the total time.

It may seem from this review as a whole that the lessons regarding the effect of heat on brake-lining materials, as shown by the early tests under both light and severe conditions and by the sticking tests, had not been properly analyzed or heeded. However, on the one hand, less was formerly expected of brake-linings and, on the other hand, many difficulties have stood in the way of making the improvements indicated by the test data. Except for these reasons the efforts of brake-lining makers might have resulted in an improvement of the frictional characteristics similar to that which has been achieved in durability.

The demand for reliable retardation to assure safety in traffic emergencies has led to placing the responsibility for good brakes on the car owner, who may keep his brakes well shod with one of the many "best" linings, but who has no control over the inherent qualities and frequently does not suspect the temperamental character of the lining material. In view of the brake-lining manufacturer's present difficulties, it is perhaps fortunate for him that, after a fatal accident, the coroner, while casting one eye on the car owner, does not yet turn the other on the creator of the brake-lining material. That manufacturers are, however, earnestly endeavoring to improve their products is evidenced by the increased

laboratory facilities and improved production methods being employed.

To reduce the many apparent discrepancies between laboratory tests and between these and the results in service, we must have a fuller knowledge of the inherent qualities of brake-linings and of the conditions occurring in service. The information already available from tests now used must be supplemented by readjustment and amplification of test schedules. Whatever the tests, they should demonstrate what may occur over the entire range of conditions, not only up to the most severe that are anticipated but also up to the very limit of every brake-lining tested. This is necessary for a full knowledge of brake-linings and to permit a grading of available linings according to the severity of service for which they are suitable; to demonstrate whether and to what extent conditions of extreme severity may cause either a dangerous reduction in the frictional qualities, or a gradual or sudden mechanical destruction; and to show what factor of safety remains under any or all conditions. The extent to which the more severe of the tests show the possible changes in the frictional qualities with sufficient detail will govern the possible reduction in the number of necessary tests under more moderate conditions.

Some brake-linings, if cooled after an application of more or less heat below a destructive amount, will recover their original character and the changes caused by heat will be repeated similarly with successive applications. In other brake-linings, similar temperatures of varying degree and period of application may result in permanent changes of character so that, for instance, a large drop in the coefficient of friction may not recur. It may therefore be necessary to include test schedules providing for such periodic applications of heat. On the other hand, it may prove possible to ascertain this feature by supplementing the other necessary running tests by volatility tests with samples of the linings.

That, according to many reports, service tests have shown that the combination of a given brake-lining with various drum-materials greatly influences durability of both lining and drum is not at all surprising. Wear tests must take this into account. It would, however, seem reasonable to test brake-linings offered or considered for general service conditions on the drum material least favorable to the durability of the linings, particularly if the drum material in most general use is of that class.

With the standard passenger-car type of drum used in the work of the Bureau of Standards, its lack of rigidity, the unsymmetrical heat-conduction and the distortion resulting from both of these factors introduce conditions unfavorable to the brake-lining; these are chargeable to brake design and should therefore preferably be eliminated from tests of linings as such. If the wearing quality of these cold-pressed, low-carbon-steel drums can be duplicated satisfactorily in a drum otherwise more satisfactory for brake-lining tests, it is preferable to use such drums.

The test equipment should, for reasons already stated, permit the making of tests on the basis of constant power-absorption. Solid brake-shoes facilitate the mounting of test-specimens. Short test-specimens reduce the tendency to uneven pressure-distribution and consequent results, as well as assist in reducing the temperature by greater exposure of the drum surface. Two opposed brake-shoes are more advantageous than a single brake-shoe as they reduce the arc covered by each test-specimen and tend to greater accuracy in determination of the coefficient of friction with the same total length of test material. They also tend toward lower temperatures, less distortion of light drums and have other minor advantages. It seems possible that the use of water-cooled drums can be avoided.

It is believed that the necessary information on the changes in the coefficient of friction as well as on the durability of the present type of brake-linings can be obtained satisfactorily by a series of consecutive tests, made with the same specimens, in which the values of the power absorption are chosen so that they will result in equilibrium temperatures of, respectively, say 150, 250 and 400 deg. cent. (302, 482 and 752 deg. fahr.). Each of these tests should be continued for a specified time and there should be a cooling interval between tests. The brake-linings may then be rated on the basis of uniformity of coefficient of friction, as shown by maximum and minimum values, and of durability. This method will now be given a try-out in the work of the Bureau of Standards.

During the last 3 years of this investigation and of the development of the equipment, I have been assisted by Carl Roeder, who made all tests. Acknowledgment is made also of the courtesy I have met in my contacts with those in the industry, and of their willingness to furnish information, including much of that presented in this paper.

Rules of the Road

"THE first rule of the road is to let the other driver behind or approaching know what you intend to do and when you intend to do it." So says the Standard Oil Co. of New York in its road maps of New York State and New England, in which it also advocates, and illustrates, the use of four simple signals, all of which are executed with the left hand.

A right turn is indicated by a clockwise revolution of the hand toward the right. The signal for a left turn is executed by pointing the index finger straight out to the left. A stop is indicated by extending the arm horizontally, with the fingers of the hand open and the palm facing forward. The "back-up" signal is given by extending the hand horizontally as for the stop signal but with the palm facing the rear. If necessary, a slight waving motion toward the rear might accompany this "back-up" gesture.

Some drivers forget to signal until the very moment they apply the brakes. Other drivers begin to signal a half block or more before they are ready to turn. Either method is likely to confuse the operator of the car behind, although it is much more desirable to give too much time than too little. The driver who signals his intentions in the brief moment before he actually turns is not only discourteous but positively dangerous.—*Motor Travel*

Automotive Research

Expositions on the subject of exhaust gas from two different points of view are included in this month's Automotive Research.

E. H. Lockwood[1], in the first contribution, presents to engineers a practical and easily applied method for turning to account the results obtained from exhaust-gas analysis. He has developed six algebraic formulas for calculating from exhaust-gas data information relating to the air and fuel constituents of combustion. In using these formulas it is necessary only to insert the numerical values of the respective items as obtained from the analysis. Professor Lockwood also explains the derivation of the formulas and gives an example of their use.

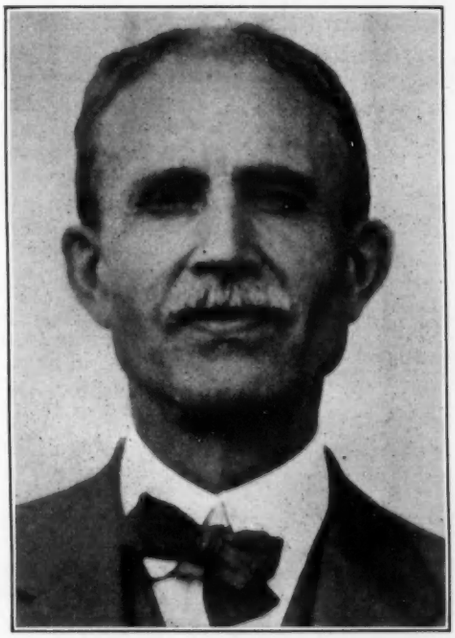
In the second contribution, Clarke C. Minter[2] explains the chemistry involved in combustion in the effort to arrive at a more accurate knowledge of the constituents of exhaust gas. He sets forth the simple stoichiometric relations that exist between the products of combustion of a hydrocarbon fuel, considering for an ideal system the volumetric relationships existing for three cases, (*a*) complete combustion, (*b*) fuel in excess and (*c*) air in excess, and then the relations between volumes and percentages of combustion products. He then discusses the correction factors that must be introduced in applying these ideal relations to combustion under actual engine conditions. This author proposes to present, in a later article, a probability method for attacking quantitatively the problem of free oxygen in exhaust gas.

EXHAUST-GAS-ANALYSIS CALCULATIONS

Analysis of exhaust gases from an internal-combustion engine may afford much useful information relating to the air and fuel constituents. In many instances but little use has been made of this information, due perhaps to absence of a direct method of deriving the information from the analysis. This article presents a method that is believed to have some elements of simplicity and completeness.

The uses to which exhaust gas analysis may be put are important and have been often emphasized. A few instances of work done by the Bureau of Mines may be cited as examples. Some analyses of exhaust gas were made at the Government Fuel Yard, City of Washington, to determine and improve the adjustment of the carbureters on the trucks used for transporting coal from the Fuel Yard to Government buildings. As a result of this investigation, carbureters were so adjusted as to effect an increase in mileage and a saving of gasoline of 22 per cent for the first month after adjustment, 16 per cent for the second and 9 per cent for the third. Other tests showed that in the average motor-vehicle approximately 30 per cent of the heat value of the gasoline passes out in the exhaust as incomplete-combustion products.

Still further research was carried out to determine the degree of uniformity in the fuel-air mixtures fed to the various cylinders of a multi-cylinder engine. In this investigation exhaust gas taken from the cylinders while the engine was in operation was analyzed. These tests showed that the front cylinder of a four-cylinder engine operating at 15 m.p.h. received 14.0 more, the second 9.6 per cent more, the third 12.8 per cent less, and the fourth 10.8 per cent less fuel than it should. With the engine tested, therefore, the carbureter could not be adjusted to give a very economical mixture, since, with such an adjustment, the mixture received by two of the cylinders would be so lean that engine trouble would be almost sure to develop.



PROF. E. H. LOCKWOOD

Engineers, it was felt, would welcome a ready means, such as is here presented, for tapping such a source of pertinent and worthwhile data as is presented in a complete and accurate analysis of the exhaust gas from an internal-combustion engine.

Exhaust-gas analysis usually is made in an Orsat apparatus, in which a measured volume of gas is passed in succession into chambers containing chemicals, the loss of volume being noted after each absorption. The items that may be determined in this way, in the order of absorption, are carbon dioxide CO_2, oxygen O_2 and carbon monoxide CO. The residue is composed, probably, of nitrogen and small quantities of hydrogen and methane H_2 and CH_4. It is not feasible to determine any of the residue by absorption. It is necessary to introduce oxygen, perform a combustion process, and compute the volume of hydrogen and methane from the changes after combustion; operations that require considerable care and experience.

When the hydrogen and methane items are not obtainable by experiment, their values may be approximated by empirical rules, a procedure that is better than complete omission of the items from the analysis. It has been noticed that hydrogen and methane are found in the exhaust gases only when carbon monoxide is present, and that their volume is roughly dependent on the amount of CO.

[1] M.S.A.E.—Associate professor of mechanical engineering, Yale University, New Haven, Conn.

[2] M.S.A.E.—Research chemist, New York City.

The following empirical rule has been suggested by A. W. Judge.[3]

$$\left.\begin{aligned} H_2 &= 0.36\ CO \\ CH_4 &= 0.12\ CO \end{aligned}\right\} \quad (1)$$

I have deduced another rule, based on theory:

$$\left.\begin{aligned} H_2 &= 5.9\ CO_2 + 4.13\ O_2 + 4.26\ CO - 85.5 \\ CH_4 &= 1/3\ H_2 \end{aligned}\right\} \quad (2)$$

A typical exhaust-gas analysis including hydrogen and methane, by which rules (1) and (2) can be tested, is as follows:

By Experiment	By Rule (1)	By Rule (2)
$H_2 = 3.0$	$= 2.52$	$= 3.25$
$CH_4 = 1.0$	$= 0.84$	$= 1.08$

Values given by the empirical rules are too small in one case and too large in the other; but either may be considered fairly good approximations.

A typical analysis of exhaust from a gasoline engine is given in the following table, derived from an investigation made by the Bureau of Mines. This particular analysis was an average from 16 different motor-cars under level-road operation at speeds from 5 to 15 m.p.h.

	Per Cent
Carbon Dioxide CO_2	8.96
Oxygen O_2	1.46
Carbon Monoxide CO	7.00
Hydrogen H_2	3.00
Methane CH_4	1.00
Nitrogen, by difference, N_2	78.58
Total	100.00

Calculations from the exhaust analysis can be made from algebraic formulas, in which the percentages of the gas-analysis items appear with definite coefficients. In using these formulas it is necessary only to insert the numerical values of the respective items and make the indicated computations. The formulas, with an illustrative example, followed by an explanation of the theory by which they were deduced, are as follows:

Computation Formulas for Exhaust-Gas Analysis

Assumed composition of exhaust gas by volume: $CO_2 + O_2 + CO + H_2 + CH_4 + N_2 = 100$. The volume percentages are to be inserted in the formulas and solved in the usual way.

Pounds of air used per pound of combustible in the fuel

$$= \frac{18.15\ N_2}{0.522\ N_2 + 4\ CO_2 + 5\ CO + H_2 + 8\ CH_4 - 2\ O_2} \quad (1)$$

Pounds of air theoretically required per pound of combustible

$$= \frac{18.15\ N_2 + 34.8\ (CO + H_2 + 4\ CH_4 - 2\ O_2)}{0.522\ N_2 + 4\ CO_2 + 5\ CO + H_2 + 8\ CH_4 - 2\ O_2} \quad (2)$$

Weight per cent of hydrogen in the combustible in the fuel

$$= \frac{0.522\ N_2 + H_2 - 2\ (CO_2 + O - CH_4) - CO}{0.522\ N_2 + 4\ CO_2 + 5\ CO + H_2 + 8\ CH_4 - 2\ O_2} \times 100 \quad (3)$$

Weight per cent of carbon in the combustible in the fuel

$$= \frac{.6\ (CO_2 + CO + CH_4)}{0.522\ N_2 + 4\ CO_2 + 5\ CO + H_2 + 8\ CH_4 - 2\ O_2} \times 100 \quad (4)$$

Pounds of water vapor formed per pound of combustible

$$= \frac{4.69\ N_2 - 18\ (CO_2 + O_2) - 9\ CO}{0.522\ N_2 + 4\ CO_2 + 5\ CO + H_2 + 8\ CH_4 - 2\ O_2} \quad (5)$$

Weight of dry gas per pound of combustible

$$= \frac{22\ CO_2 + 16\ O_2 + 14\ (CO + N_2) + H_2 + 8\ CH_4}{0.522\ N_2 + 4\ CO_2 + 5\ CO + H_2 + 8\ CH_4 - 2\ O_2} \quad (6)$$

Computation check:

1 lb. of fuel + air by formula (1) = water by formula (5) + dry gas by formula (6)

These formulas have been deduced by theoretical reasoning as explained in a later paragraph. When the formulas are applied to different analyses from an engine using the same fuel, the results obtained from formulas (1), (5) and (6) will vary in accordance with the fuel-air ratio, while the results by formulas (2), (3) and (4) will be constant within the limits of incidental errors of analysis and computation. For a gasoline engine, for example, formula (2) should yield a value of 15.1 to 15.2 lb. of air per lb. of combustible for all analyses. Constancy of this figure may well be considered a satisfactory proof of the correctness of analysis and computation, while any considerable departure from it may be regarded as an indication of error.

Illustrative example, from the Bureau of Mines analysis given in a preceding paragraph, follows

Air used per pound of combustible, formula (1), lb., 11.90

Air theoretically required per pound of combustible, formula (2), lb., 15.1

Hydrogen in combustible, formula (3), per cent, 15.15

Carbon in combustible, formula (4), per cent, 84.85

Water vapor per pound of combustible, formula (5), lb., 0.98

Dry gas per pound of combustible, formula (6), lb., 11.92

Check: 1 lb. of fuel + air = 12.90

Water vapor + dry gas = 12.90

Derivation of Exhaust-Gas-Analysis Formulas

Preliminary Assumptions.—Fuel is composed of carbon and hydrogen, whose sum is called the combustible in the fuel, and a small percentage of non-combustible substances. In the case of refined fuels like gasoline, the combustible is practically 100 per cent of the total weight.

Air is composed of oxygen (23 per cent by weight) and nitrogen (77 per cent by weight); and water vapor in the air is neglected.

Composition of the exhaust gas is known by volumetric analysis, consisting of the following items:

$$CO_2 + O_2 + CO + H_2 + CH_4 + N_2 = 100$$

The weight of all the substances connected with the combustion can be expressed by the relation: weight = density × volume. A particular application of this rule can be made, when no special unit is desired, by using the molecular weight instead of the density, and the gas-analysis percentage instead of the volume.

Expressions can be written in this way for the weights of all the substances referred to, as follows:

WEIGHT OF

Nitrogen, $28\ N_2$ (7)

Carbon dioxide, $44\ CO_2$ (8)

Carbon monoxide, $28\ CO$ (9)

Oxygen, $32\ O_2$ (10)

Unburned hydrogen, $2\ H_2$ (11)

Methane in exhaust, $16\ CH_4$ (12)

Carbon in exhaust, $12\ (CO_2 + CO + CH_4)$ (13)

Hydrogen = hydrogen burned + hydrogen unburned

Hydrogen burned = 1/8 oxygen combined with hydrogen

Oxygen combined with hydrogen = total oxygen used less oxygen in dry gas

Air, $28\ N_2/0.77 = 36.3\ N_2$ (14)

Oxygen in air, $0.23 \times 36.3\ N_2$ (15)

Oxygen in dry gas, $32\ (CO_2 + O_2) + 16\ CO$ (16)

Oxygen combined with hydrogen $= 8.34\ N_2 - 32\ (CO_2 + O_2) - 16\ CO$ (17)

Hydrogen burned, 1/8 of above, $= 1.043\ N_2 - 4\ (CO_2 + O_2) - 2\ CO$ (18)

Hydrogen, total, $= 1.043\ N_2 - 4\ (CO_2 + O_2) - 2\ CO + 2\ H_2 + 4\ CH_4$ (19)

Combustible, sum of (13) + (19) $= 1.043\ N_2 + 8\ CO_2 + 10\ CO - 4\ O_2 + 2\ H_2 + 16\ CH_4$ (20)

Water vapor formed by burning hydrogen, 9 × (18) $= 9.39\ N_2 - 36\ (CO_2 + O_2) - 18\ CO$ (21)

Dry gases, sum of (7) to (12) inclusive $= 28\ (N_2 + CO) + 44\ CO_2 + 32\ O_2 + 2\ H_2 + 16\ CH_4$ (22)

[3] M.S.A.E.—See Testing of High-Speed Internal-Combustion Engines, p. 103.

Air theoretically required for complete combustion of carbon and hydrogen,

$$11.6 \times \text{carbon} + 34.8 \times \text{hydrogen} = 36.3\,N_2 + 69.6\,(CO - 2\,O_2 + H_2 + 4\,CH_4) \qquad (23)$$

DERIVATION OF FORMULAS (1) TO (6)

The various weights as given in the foregoing list are stated in the same units, hence can be directly compared, giving the expressions as written in the section entitled Computation Formulas for Exhaust-Gas Analysis.

Formula 1.—Pounds of air per pound of combustible, divide (14) by (20)

Formula 2.—Pounds of air theoretically required per pound of combustible, divide (23) by (20)

Formula 3.—Weight per cent of hydrogen in combustible, divide (19) $\times$ 100 by (20)

Formula 4.—Weight per cent of carbon in combustible, divide (13) $\times$ 100 by (20)

Formula 5.—Pounds of water vapor per pound of combustible, divide (21) by (20)

Formula 6.—Weight of dry gas per pound of combustible, divide (22) by (20)

E. H. Lockwood.

INTERPRETATION OF EXHAUST GAS

The simple volumetric determination of carbon dioxide in exhaust gas is generally regarded as a satisfactory indication of the mixture strength, and for most purposes it is sufficient. Strictly speaking, however, the percentage of carbon dioxide, no matter how accurately it is determined, can furnish only a qualitative indication of the air-fuel ratio. For research purposes, it becomes necessary to know all the constituents of the exhaust, the composition of the fuel and the conditions under which the engine is running. In addition, it is necessary to confine the sampling to individual cylinders, because of unequal distribution. For instance, a sample drawn from the exhaust conduit near the engine will contain a mixture of gases from the different cylinders, but it is not generally recognized that the sample does not represent a true mean of all the cylinders. This discrepancy is the result of the variation of the temperature of the exhaust with the air-fuel ratio, and in cases where the distribution is not good, a sample of the exhaust from all the cylinders will contain a larger proportion of gas from the richer cylinders.

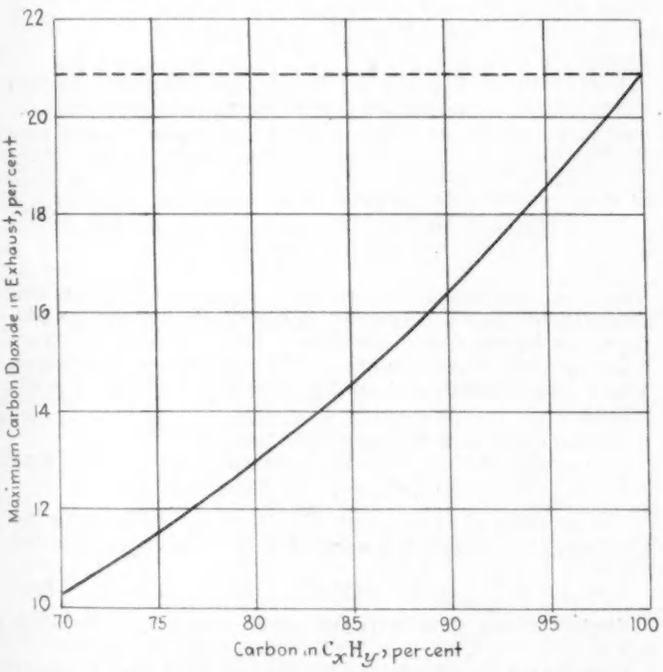


FIG. 1—VARIATION OF VOLUME PERCENTAGE OF CO_2 IN EXHAUST WITH THE CARBON CONTENT OF SIMPLE HYDROCARBON FUELS

The Curve Is Based on Calculations for an Ideal System and Is True Only for Cases in Which Combustion Is Complete

When combustion research is undertaken, so many apparently trivial effects have to be taken into account if quantitative accuracy is desired that a good working knowledge of the chemistry involved must be obtained. In what follows it will be shown that simple stoichiometric relations exist between the products of combustion of a hydrocarbon fuel. A working knowledge of these relations is necessary in any sort of quantitative combustion-research involving final products. They are derived solely from the atomic weights and combining proportions of the elements involved, and could be found by any chemist without much trouble. They are given here for the reason that they have never before appeared in print, although they have doubtless been used many times by chemists who have not published them.

IDEAL VOLUMETRIC RELATIONS

In every case the fuel is regarded as added to 100 volumes of air. That is, the air-fuel ratio is varied by using a definite quantity of air and varying amounts of fuel. This simplifies the matter, in that 20.9 volumes of oxygen are used in every case, leaving only nitrogen and combustion products, except when very lean mixtures are used. Three cases will be considered: (*a*) Air and fuel in such proportions that all the fuel is completely converted to CO_2 and H_2O, (*b*) fuel in excess and (*c*) air in excess.

As to correct proportions of fuel and air, if the composition of the hydrocarbon is known, it is a simple matter to calculate the volume percentage of CO_2 in the exhaust when all the fuel is burnt. Since 1 gram-atom of carbon combines with one *volume* of oxygen, and 4 gram-atoms of hydrogen combine with one *volume* of oxygen, the total volume of oxygen used is given by the percentages of carbon and hydrogen divided by the gram-atoms of each used. If pC and pH are the weight percentages of carbon and hydrogen in the fuel, and the atomic weights are 12 and 1, we have pC/12 and pH/4 as the volumes of oxygen used by each element. Since the volume of nitrogen in air is 3.78 times the oxygen, and the exhaust contains only CO_2 and nitrogen, the volume percentage of CO_2 in the exhaust is given by the relation

$$p\text{CO}_2 = \frac{100 \times p\text{C}/12}{3.78\,(p\text{C}/12 + p\text{H}/4) + p\text{C}/12} = \frac{100\,p\text{C}}{4.78\,p\text{C} + 11.34\,p\text{H}} \qquad (1)$$

This relation is fairly general and applies to the hydrocarbons of any series. It shows that the exhaust resulting from the complete combustion of benzene contains 17.4 per cent of CO_2. For a paraffin containing 8 atoms of carbon, the percentage of CO_2 is 14.4. For the olefins, naphthenes and paraffin mono-alcohols, regardless of the number of carbon atoms in the molecule, the percentage of CO_2 in the exhaust is the same and has the value 15 per cent. In Fig. 1 is shown the variation of the percentage of CO_2 obtained from the complete combustion of simple hydrocarbons of varying carbon content.

The air-fuel ratio at complete combustion of a fuel of known composition is obtained from the relation

$$0.115\,(p\text{C} + 3p\text{H}) \qquad (2)$$

which, for octane, C_8H_{18}, gives the value 15.1. For every 100 volumes of air used in a mixture giving complete combustion, the actual volume of CO_2 formed is

$$20.9\,[p\text{C}/(p\text{C} + 3\,p\text{H})] \qquad (3)$$

and the actual volume of water formed is

$$125.4\,[p\text{H}/(p\text{C} + 3\,p\text{H})] \qquad (4)$$

The ratio of the volume of H_2O to the volume of CO_2 is

$$6p\text{H}/p\text{C} \qquad (5)$$

The value of this ratio can also be calculated from the chemical equation

$$C_nH_{2n+2} + \frac{3n+1}{2}O = nCO_2 + (n+1)H_2O \qquad (6)$$

representing the combustion of a paraffin. We have $6p\text{H}/p\text{C} = (n+1)/n$, which in the case of octane is $9/8 = 1.125$.

Relation (6) contains enough information to enable us to calculate the volumes of CO_2 and H_2O formed. Taking the volume percentage of oxygen in the air as 20.9, we obtain for the volume of CO_2, $20.9\ [2n/(3n+1)]$, and for the volume of H_2O, $20.9\ [(2n+2)/(3n+1)]$. For octane, where $n=8$, we find that from 100 volumes of air there are formed 13.37 volumes of CO_2 and 15.04 volumes of H_2O. The ratio 15.04/13.37 is 1.125 as obtained above.

Mixtures Containing Fuel in Excess

When the mixture contains an excess of fuel, the combustion is said to be incomplete in the sense that there is not enough oxygen present to burn all the fuel to CO_2 and H_2O. There will be, in such cases, a residue of unburnt fuel which takes the form CO and H_2. Since it is obvious that equal volumes of CO and CO_2 are formed from a given quantity of carbon, and that one volume of H_2O contains only one volume of H_2, we find that the value of the ratio $(H_2O+H_2)/(CO_2+CO)$ is independent of the amount of fuel used. The ratio has, in fact, the same value as that already determined for the ratio of the volumes of H_2O and CO_2 at complete combustion, namely $6pH/pC$.

At any air-fuel ratio R, when 100 volumes of air are used the volume (CO_2+CO) is

$$2.4\ (pC/R) \tag{7}$$

Similarly, the volume (H_2O+H_2) is

$$2.4\ (6pH/R) \tag{8}$$

The total volume of all products of combustion is evidently

$$2.4\ (pC+6\,pH)/R. \tag{9}$$

To obtain the increase in volume subtract 20.9 from relation (9).

Knowing vCO_2 and vCO, it is possible to calculate the air-fuel ratio. Remembering that 13.37 volumes of CO_2 are formed at complete combustion from 100 volumes of air when octane is the fuel, the air-fuel ratio is found by the simple proportion $(vCO_2+vCO):13.37::15.1:R$, where R is the air-fuel ratio. Solving, we have

$$R=\frac{202}{vCO_2+vCO} \tag{10}$$

Since 15.04 volumes of H_2O are formed from 100 volumes of air, we derive a similar proportion for (vH_2O+vH_2) and find that, in this case,

$$R=\frac{227.3}{(vH_2O+vH_2)} \tag{11}$$

From relation (11) we can calculate the volume of H_2O formed at any air-fuel ratio, and find that

$$vH_2O=(227.3/R)-vH_2 \tag{12}$$

Recalling that the ratio $(vH_2O+vH_2)/(vCO_2+CO)=1.125$ for octane, another simple relation for calculating the volume of water is given by

$$vH_2O=1.125\ (vCO_2+vCO)-vH_2 \tag{13}$$

Since 100 volumes of air contain 20.9 volumes of O_2, we have $vCO_2+vCO/2+vH_2O/2=2.09$, from which

$$vH_2O=41.8-2vCO_2-vCO \tag{14}$$

which furnishes still another method of calculating the volume of water when the other volumes are known.

Mixtures Containing an Excess of Air

Such mixtures are so rarely found in practice that only a brief treatment is necessary. In such cases the volumes of the products of combustion of fuel octane are

$$vCO_2=202/R \tag{15}$$

and

$$vH_2O=\frac{227.3}{R} \tag{16}$$

The total volume after combustion is

$$100+11.7/R \tag{17}$$

and the percentages of the constituents of the exhaust are found from the relations

$$pN_2=79.1R/(100R-113.7) \tag{18}$$

$$pCO_2=202/(100R-113.7) \tag{19}$$

$$pO_2=\frac{20.9R-315.7}{100R-113.7} \tag{20}$$

[4] See The Journal, June, 1925, p. 613.

Relations Between Volumes and Percentages of Combustion Products

This part of the discussion is confined to those mixtures containing an excess of fuel, in which all the oxygen has been used. Since one volume of O_2 produces one volume of CO_2, the formation of CO_2 does not affect the total volume after combustion. On the other hand, the formation of CO and H_2O produce an increase in volume since one volume of O_2 will produce two volumes of either of these gases. In addition, the residual hydrogen will contribute to the final volume, producing an increase. Finally, the water is condensed out before the exhaust is analyzed. So that, in the end, instead of the 100 volumes taken at the start, we have to take into consideration three changes and determine the resultant effect of them all. First, a certain amount of O_2 has doubled in volume in the formation of CO; second, a certain volume of H_2 has been added; and, finally, a certain volume of O_2 has been removed in the form of water.

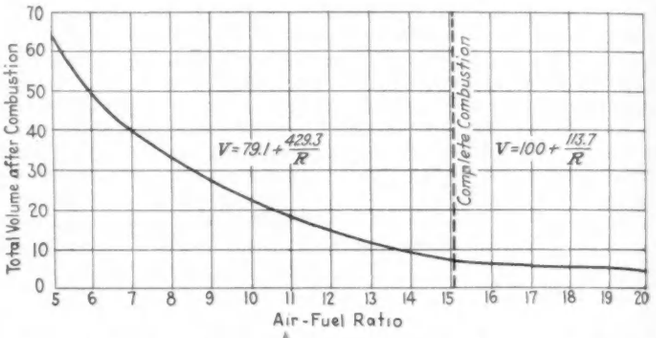


Fig. 2—Total Volume of Combustion Products Plotted against Air-Fuel Ratio, with Octane as Fuel

This Is Presented as an Illustration of the Method Developed for Determining the Resultant Effect of Three Volume Changes Due to Combustion, (*a*) Doubling of Volume of Some O_2 in the Formation of CO, (*b*) Addition of H_2 and (*c*) Removal of O_2 in the Form of Water, on the Ideal 100 Volumes of Air with Which the Process Is Considered as Starting. The Discussion Developing This Method Is Confined to Mixtures Containing an Excess of Fuel

The first two changes produce an increase, and the condensation of H_2O a decrease. Whether the net change produces an increase or a decrease in the 100 volumes taken originally can be determined by the percentage of nitrogen, pN_2, in the exhaust, and we have the three following possibilities.

$$\begin{aligned}&\text{When } (vH_2+vCO/2)>vH_2O/2, \text{ then } pN_2<79.1;\\ &\text{When } (vH_2+vCO/2)=vH_2O/2, \text{ then } pN_2=79.1;\\ &\text{When } (vH_2+vCO/2)<vH_2O/2, \text{ then } pN_2>79.1.\end{aligned} \tag{21}$$

The relation of the volume of CO_2 in the cylinder to the percentage of CO_2 in the exhaust, is therefore, represented by

$$vCO_2=pCO_2\ (79.1/pN_2) \tag{22}$$

Similarly, we have for the other combustion products $vCO=pCO\ (79.1/pN_2)$ and $vH_2=pH_2\ (79.1/pN_2)$.

Owing to the difficulty of obtaining rapid and accurate determinations of CO, the author has in many cases determined only the H_2 and the CO_2 using a thermal conductivity method.[4] Since the percentage of nitrogen in the exhaust was not known, another method was used for calculating the volumes of the combustion products when the only data known were the percentages of CO_2 and H_2. The following ideal relations are used, $pN_2+pCO_2+pH_2=100$; or

$$pN_2+pCO=100-(pCO_2+pH_2) \tag{23}$$

Also

$$(79.1+vCO)/(pN_2+pCO)=(vCO_2+vH_2)/(pCO_2+pH_2) \tag{24}$$

If relation (23) is substituted in relation (24), we have

$$(79.1+vCO)=\frac{(vCO_2+vH_2)\ (100-pCO_2-pH_2)}{pCO_2+pH_2} \tag{25}$$

Referring to relations (13) and (14) it can be seen that if the two are equated and solved for vCO, the result is

$$vCO = \frac{41.8 + vH_2 - 3.125\, vCO_2}{2.125} \qquad (26)$$

Since it is obvious that the relation $vH_2 = (pH_2/pCO_2)\, vCO_2$ exists, it can be seen that all the unknowns except vCO_2, pCO_2 and pH_2 can be eliminated. Since pCO_2 and pH_2 can be determined by analysis, we can obtain the volume of CO_2 by the relation

$$vCO_2 = \frac{209.88\, pCO_2}{212.5 + pCO_2 - 3.125\, pH_2} \qquad (27)$$

After obtaining the volume of CO_2 from this relation, the other volumes can be calculated from the relations given above.

It is important that volume relations are used in calculations where the physical chemistry of the combustion process is being studied. If desired, the volumes can be converted into percentages in the mixture before exhaustion occurs. In Fig. 2 the total volume after combustion is plotted against air-fuel ratio, when octane is the fuel.

The relations given above are independent of the operation of any equilibrium between the products of combustion. If the equilibrium $CO_2 + H_2 \leftrightarrow CO + H_2O$ exists, shifts in the equilibrium will not change the total volume of combustion products when a definite quantity of fuel is added to 100 volumes of air. However, the several ratio relations which can exist among the volumes of the different combustion products assume different values as the equilibrium shifts.

Analysis of the Fuel

If a number of determinations of the percentages of CO_2 and H_2 are made when running an engine on a fuel of unknown composition, it is possible to use the figures so obtained to calculate the percentage of carbon in the fuel. The air-fuel ratio must be varied over a considerable range, somewhere between the point of complete combustion and that giving maximum power. If the percentages of CO_2 and H_2 so obtained are plotted and the straight line connecting the points extrapolated until the CO_2 axis is intersected, the point of intersection will give the percentage of CO_2 in the exhaust at complete combustion. If $(100 - pC)$ is substituted for pH in relation (1), pC can be calculated when pCO_2 is known.

Conclusions

It has already been pointed out that these relations are ideal, and many correction factors have to be introduced before they can be applied to the combustion of hydrocarbons under actual engine conditions. In the first place, it is never known how much lubricating oil is burnt along with the fuel. Since the oil is practically all paraffins, the error is almost negligible when a paraffin fuel is used, but the correction factor is appreciable when other hydrocarbons are used as fuel. The exhaust has to be taken as the combustion products of a charge consisting of air and hydrocarbons, regardless of what proportion of the hydrocarbons is delivered by the carbureter or is contributed by the lubricating oil.

The exhaust always contains small amounts of partial oxidation products, such as alcohols, acids and aldehydes of the hydrocarbons in the fuel. These, however, can be ignored. A certain quantity of gaseous hydrocarbons can always be found in the exhaust, being produced by the cracking of liquid hydrocarbons. It is believed that most of this cracking occurs when the oil-film on the cylinder-wall is exposed during the power and exhaust strokes. For this reason, it is thought that the hydrocarbon content of the exhaust should not be included in the calculation of the composition of the fuel from exhaust-gas data. The hydrocarbon residue can just as well be produced by the cracking of a portion of the lubricating oil, and since the cracking is regarded as taking place after the combustion is finished, there is hardly any justification for regarding the hydrocarbons as a product of the combustion. When the percentage of hydrocarbons in the exhaust is known, a correction is applied to the percentages of the products of combustion, resulting in a slight increase in the percentages, which, in most cases, is negligible.

It has been observed that free oxygen is always present in the exhaust, even when very rich mixtures are used. The presence of oxygen in the exhaust when the charge contains an excess of fuel is the most disturbing feature about all combustion calculations, and no satisfactory explanation of its presence has ever been suggested. Attempts have been made to correct for the oxygen in the exhaust when the charge contains an excess of fuel, particularly when trying to calculate the volume of water formed in the combustion. All such attempts are objectionable, and the results so obtained are of little value in research work.

The conclusion has been reached that the presence of free oxygen in the exhaust can be explained by assuming an unequal distribution of fuel in the charge. Even when the fuel is in excess, a portion of the charge will contain air in excess. The charge will then burn as a "mixture of mixtures," and the lack of uniformity will show up in the exhaust-gas analysis. The problem has been attacked quantitatively by the method of probabilities, and appears very promising. A discussion of the probability method will soon be published.

Growth of the Gas Industry

ONE of the great pages in American industrial and economic history is being written today by the gas industry. With more than a century of public service and progress as testimony to its stability, this industry has doubled its sales in the last decade and quadrupled them in the last 20 years. Two present fields for expansion, house heating and industrial heating, are so fraught with possibilities that it is no exaggeration to say that the carbonization of coal, as carried on in the modern gas-plant, and the sale of the gas and resulting by-products, will exert a powerful influence over the economic life of the entire Nation.

In an era of gas production in mammoth plants with long-distance transmission at high pressure, it is apparent that the advantages of gas as a fuel are so many and so pronounced that wide acceptance is merely a matter of relatively few years.

The application of gas to innumerable processes of industry opens a field of practically unlimited proportions. Today the American Gas Association is spending $500,000 on scientific research to develop suitable appliances using gas for many of industry's heat problems that have been troublesome for years. In 1910 only 5 per cent of the gas output, or 7,500,000,000 cu. ft., was sold to industry. In 1926, 25 per cent of the gas sold was for this purpose, representing an increase of 1500 per cent since 1910. The latest estimate places gas as a useful fuel in more than 21,000 industrial and factory operations.—Harry C. Abell, ex-president of the American Gas Association.

Production Engineering

PRODUCTION ENGINEERING STANDARDS

Three classes of standardization that may help the work of the production engineer are:

(1) Interindustrial standardization, which is of such a broad nature that it may affect work in more than one industry
(2) Industrial standardization, which is undertaken primarily for the benefit of a single industry
(3) Company standardization, which is undertaken by a sigle manufacturing organization for its own work.

These three classes overlap somewhat. For instance, the S.A.E. Standards in general belong in the second class, but many of the individual standards include lists of sizes beyond the range of use in the automotive industry that are useful in other industries; and a considerable part of any company standardization may be based on the work of the first two classes to the extent of adopting certain of the industrial and interindustrial standards as a whole or insofar as they apply to the work of that company.

In this department this month is an article on Machine-Tool Standardization that refers to one of the activities of the interindustrial standards organization of this Country. Another article, on Tool Standardization, gives an excellent example of company standardization. An interesting point in regard to the latter article is that it illustrates so well the adaptation of general standardization to the requirements of an individual manufacturing organization.

We cannot all be passengers in this standardization work; if the work is to be well done, it must have the benefit of constructive criticism by practical men while the standards are being formulated. It has been the experience of the past that the men and the organizations that receive the most benefit from standardization are those that helped in its formulation.

TOOL STANDARDIZATION

Some Tools and Details of Jigs and Fixtures Standardized in Beloit Plant

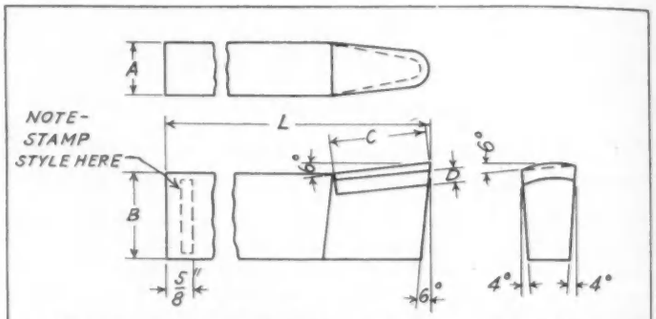
Products of our plant are very diversified, including Diesel engines of all sizes and types, small gasoline engines and farm lighting-plants. The problem of tool equipment is therefore rather complex, as the equipment must be suitable for both small and large-quantity production.

Through simplification and standardization of grinding wheels, small tools, jig and fixture details, punches and dies, and other items, many thousands of dollars can be saved annually, and it is the purpose of this article to tell something of the work we have been doing.

Grinding Wheels

No doubt the most difficult problem, yet one in which the greatest reduction in inventory can be made, is the simplification of grinding wheels. To accomplish this it was necessary to run many tests, and the results were reported in detail on a form that is very complete and is always available for reference. Through a process of elimination we have reduced the number of sizes, shapes, grains, and grades of wheels from 135 to 80, which we are using as standard, eliminating 55 of the original number. Of the 80 adopted, 53 are stock items with one grinding-wheel manufacturer. In some cases it was necessary to change or replace wheel adapters and make other slight changes to our equipment.

The list of sizes and shapes adopted by the Grinding Wheel Manufacturers Association and approved by the Production Division of the S.A.E. Standards Committee includes the majority of the wheels we found necessary.



H.S.S. SOLID STYLE-M	H.S.S. TIP STYLE-M	GRADE No.3 STELLITE TIP STYLE-M	DIMENSIONS A	B	C	D	L	HAYNES STELLITE STYLE
M-HS 3	M-HT 3	M-ST 3	1 1/4	1 1/2	2 1/4	3/8	13	M
M-HS 1	M-HT 1	M-ST 1	5/8	1 1/4	1 1/2	3/8	7	M
M-HS 2	M-HT 2	M-ST 2	3/4	1 1/2	1 1/2	3/8	7	M

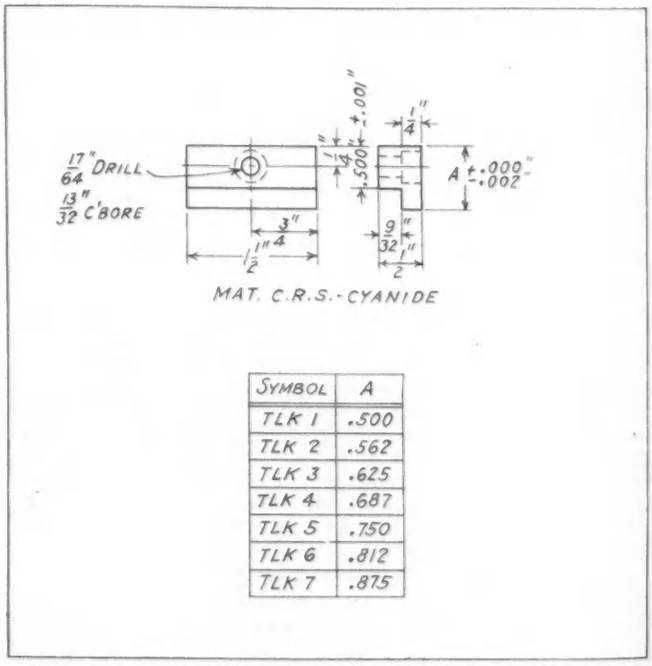
REMARKS-
MATERIAL-BODY-CARBON STEEL WITH HIGH SPEED STEEL TIP OR STELLITE TIP GRADE No.3

FIG. 1—A CUTTING-TOOL STANDARD

One Style of Cutting Tool Is Shown with a Table of Symbols for Various Materials and Sizes

Drills, Taps and Milling Cutters

Drills of special length or diameter, taps of special length or pitch diameter, special milling-cutters and variations of other standard small tools are extremely expensive. The necessity for each item of this sort was carefully investigated, with the result that changes were made in jigs, fixtures and



SYMBOL	A
TLK 1	.500
TLK 2	.562
TLK 3	.625
TLK 4	.687
TLK 5	.750
TLK 6	.812
TLK 7	.875

FIG. 2—LOCATING-KEYS FOR MILLING-MACHINE FIXTURES

Keyways in Fixtures Are Made All of One Width and Adapting Keys Are Standardized for Various Milling-Machine Slots

other equipment whenever we could thereby make it possible to use standard tools.

Our tap standards all conform to the recent standards approved by the Society. The milling-cutter manufacturers and the Division of Simplified Practice of the Department of Commerce have done considerable work in simplifying cutter sizes. Whenever possible these sizes are adhered to.

Tool-Post Openings and Tools

An analysis of our tool-post openings was made to guide us in reducing the number of tool-shank widths and heights. In some cases it was necessary to alter tool posts or rockers, but the expense of this was trivial. Having determined the shank sizes, it was next necessary to investigate the work and determine the tool shapes and lengths. The number of sizes and styles we formerly carried was reduced by approximately one-half. This also reduced our inventory of steel.

It was possible to make tools in larger quantity, thus reducing cost. Fig. 1 is an example of the way these tools are tabulated and symbolized. Checking the shank sizes we adopted as standard with the latest tentative report of the Sectional Committee on Tool Holders and Tool-Post Openings, for which the Society is one of the joint sponsors under the procedure of the American Engineering Standards Committee, we find very few instances in which it will be necessary to make a change to secure agreement.

Jig, Fixture and Die Details

The standardization of details of jigs, fixtures and dies has these advantages:

(1) Reduction of tool-design time, as the standardized parts needed are specified on the bill of materials

(2) Reduction of tool-room labor, as parts are made in quantities and held in tool-room stock

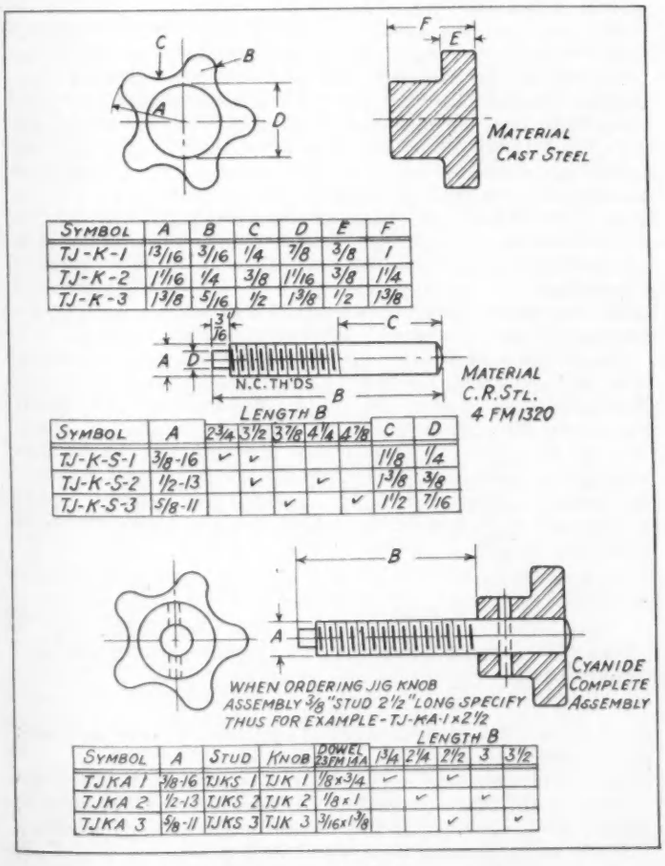

C
B
A
D
F
E
MATERIAL
CAST STEEL
SYMBOL A B C D E F
TJ-K-1 13/16 3/16 1/4 3/8 3/8 1
TJ-K-2 1 1/16 1/4 3/8 1 1/16 3/8 1 1/4
TJ-K-3 1 3/8 5/16 1/2 1 3/8 1/2 1 3/8
3/16
C
A
D
N.C. TH'DS
B
MATERIAL
C.R.STL.
4 FM 1320
LENGTH B
SYMBOL A 2 3/4 3 1/2 3 7/8 4 1/4 4 7/8 C D
TJ-K-S-1 3/8-16 ✓ ✓ 1 1/8 1/4
TJ-K-S-2 1/2-13 ✓ ✓ 1 3/8 3/8
TJ-K-S-3 5/8-11 ✓ ✓ 1 1/2 7/16
B
A
CYANIDE
COMPLETE
ASSEMBLY
WHEN ORDERING JIG KNOB ASSEMBLY 3/8" STUD 2 1/2" LONG SPECIFY THUS FOR EXAMPLE - TJ-KA-1 x 2 1/2
LENGTH B
SYMBOL A STUD KNOB DOWEL 23FM14A 1 3/4 2 1/4 2 1/2 3 3 1/2
TJKA 1 3/8-16 TJKS 1 TJK 1 1/8 x 3/4 ✓ ✓
TJKA 2 1/2-13 TJKS 2 TJK 2 1/8 x 1 ✓ ✓
TJKA 3 5/8-11 TJKS 3 TJK 3 3/16 x 1 3/8 ✓ ✓

Fig. 3—Screws and Knobs for Jigs

Three Sizes of Knobs and Screws, with Two Screw-Lengths for Each Size, Fill All Needs

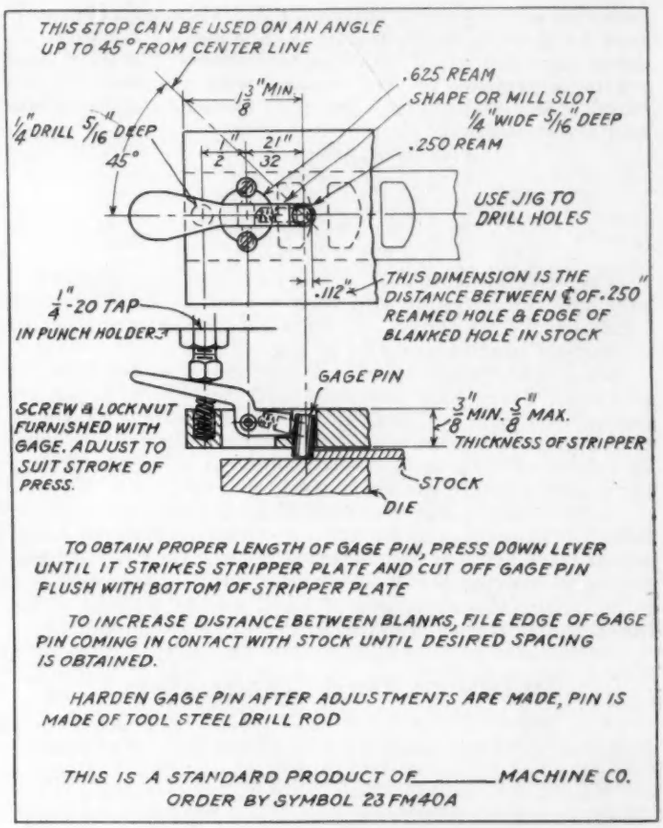

THIS STOP CAN BE USED ON AN ANGLE UP TO 45° FROM CENTER LINE
1 3/8" MIN.
.625 REAM
SHAPE OR MILL SLOT 1/4" WIDE 5/16" DEEP
1/4" DRILL 5/16" DEEP
45°
1" 2 1" 32
.250 REAM
USE JIG TO DRILL HOLES
.112"
THIS DIMENSION IS THE DISTANCE BETWEEN ℄ OF .250" REAMED HOLE & EDGE OF BLANKED HOLE IN STOCK
1/4"-20 TAP IN PUNCH HOLDER
GAGE PIN
SCREW & LOCKNUT FURNISHED WITH GAGE. ADJUST TO SUIT STROKE OF PRESS.
3/8" MIN. 5/8" MAX. THICKNESS OF STRIPPER
STOCK
DIE
TO OBTAIN PROPER LENGTH OF GAGE PIN, PRESS DOWN LEVER UNTIL IT STRIKES STRIPPER PLATE AND CUT OFF GAGE PIN FLUSH WITH BOTTOM OF STRIPPER PLATE
TO INCREASE DISTANCE BETWEEN BLANKS, FILE EDGE OF GAGE PIN COMING IN CONTACT WITH STOCK UNTIL DESIRED SPACING IS OBTAINED.
HARDEN GAGE PIN AFTER ADJUSTMENTS ARE MADE, PIN IS MADE OF TOOL STEEL DRILL ROD
THIS IS A STANDARD PRODUCT OF _____ MACHINE CO.
ORDER BY SYMBOL 23 FM 40A

Fig. 4—An Automatic Die-Gage

All Information Needed in Drafting Room and Shop for the Application of This Stock-Stop to a Punch-Press Die Is Shown on an 8½ x 11-In. Blue-Print

(3) Rapid replacement of parts, resulting in lower repair costs

(4) Reduced inventory of steel, screws, and other stock due to the elimination of many sizes

Some of the detail parts that can be standardized are:

Liner bushings	Bayonet-type screws
Slip bushings	Guide pins
Stationary drill-bushings	Guide-pin bushings
Bushing lock-screws	Fixture jack-screws
Rotating bushings	Jig knobs and screws
Jig-clamp springs	Jig and fixture buttons
Cutter set-gages	Hand-wheels
Jig-leaf screws	Fixture bases
Locating keys	Jig angles
Swivel washers	Die shoes

Punch holders

All standardized details are symbolized and tabulated for ready reference. A few examples will be of interest. Key slots in milling fixtures for locating the fixtures on the machine usually are milled the same width as the slot or keyway in the machine table. Variation in table slots causes trouble in moving a job from one machine to another. To remedy this we mill key slots in all fixtures to a standard width and provide adapter keys, as shown in Fig. 2.

All our milling fixtures have blocks for setting cutters in relation to work-locating points. All these are designed to use 0.1875-in. set-gages that are available at the tool cribs.

Jig knobs and screws are used extensively. Fig. 3 shows the form and dimensions of the few that fill our needs, together with directions for ordering them on the bill of materials for a jig.

A considerable reduction has been made in the number of sizes of steel used in tool work; also the variety of such purchased items as screws, studs and dowels. Information as to the sizes of each item that has been standardized is

issued on a blue-print of standard 8½ x 11-in. size, such as is used for the data shown in Figs. 1, 2, 3 and 4. For instance, dowel pins are given classification number 23FM14A and are to be specified by that number, with the diameter and length stated in addition. The sizes of dowel-pins standardized are as follows:

⅛ x ¾ and 1 in.
3/16 x ⅞ and 1⅜ in.
¼ x 1 and 1⅝ in.
⅜ x 1⅜, 1¾ and 2⅛ in.
½ x 2 and 2¾ in.

It is intended to tabulate in this way only such data as will save time in designing and that are not found in printed handbooks. An example of a data sheet about a specialized commercial product is shown in Fig. 4.

Merely gathering a lot of tool standards does not solve the problem. Every man connected with tool work in the organization should be "sold" on the subject, as it is very easy to deviate from any standard and many reasons can be found, by anyone who is not entirely willing to cooperate, why a particular standard cannot be used.

Standardization without simplification does not get results. I know of one instance in which 15 sizes of handwheels were listed as standard and, after a thorough investigation, it was found that three sizes fill all requirements.—F. W. Stein, superintendent of small engine division, Fairbanks, Morse & Co., Beloit, Wis.

MACHINE-TOOL STANDARDS

Reports Nearing Completion on Projects under American Engineering Standards Committee Procedure

Only within the last 2 or 3 years has definite interest begun to crystallize in the standardization movement in this Country in its application to machine-tools, small tools, and their associated equipment, such as jigs and fixtures. The field for this activity is necessarily a very broad one, touching all lines of mechanical industry, and therefore it is fitting that the work should be carried on under the National scope and procedure of the American Engineering Standards Committee, of which this Society is a member body.

The Sectional Committee on Small Tools and Machine-Tool Elements was organized originally under the sponsorship of the American Society for Mechanical Engineers and the National Machine Tool Builders Association, this Society later becoming a co-sponsor. The members of the Committee are well qualified to consider tool-standardization projects in their many aspects because of the broad and responsible industrial positions they hold. Members of this Committee frequently are also members of particular project committees, although generally their relation to committees for individual projects is advisory and directing.

Projects so far taken up under this Sectional Committee are: T-slots for machine-tools, for which the report has been completed and published; tool-holders and tool-post openings; milling cutters, and machine tapers. The Committee on Milling Cutters has circulated its tentative report and probably will take early action toward its completion. In connection with the work on machine tapers, a questionnaire has been circulated for information from the industries as to whether one or more tapers should be included in a standard, and what such tapers should be.

Subjects that probably will be taken up before long are spindle noses and taps. The tentative report on tool-holders and tool-post openings was printed in the Production Engineering department of the May, 1927, issue of THE JOURNAL, p. 572, and the report on shell-end mills was printed in the same department of the June, 1927, issue of THE JOURNAL, p. 712. Thus the reports have been placed before the automotive industry in general with the object of securing constructive suggestions for improvement that production engineers may feel should be considered by the committees responsible for the reports before their final adoption.

The interest that has been taken by the tool-manufacturing industry in the standardization movement indicates clearly an inclination to incorporate the standards in its products as soon as practicable, because the builders recognize the economic advantage of so doing. This advantage will accure eventually also to the purchasers of tools, and the committees responsible for the standards greatly desire that the user industries cooperate fully with them while the standards are in the formative stage. The Society, therefore, as the sponsor representing the automotive industries, which undoubtedly constitute the largest single group of machine-tool purchasers, is endeavoring to secure the industries' help in formulating the standards. Any suggestions or constructive criticisms concerning the proposed standards that have been published should be addressed to the Standards Department of the Society in New York City.

THE TRINITY OF INDUSTRY

Too often is industry referred to as a partnership of two: capital and labor. More accurately it should be termed a trinity; capital, labor and management.

Perhaps the comparative youth of the third member accounts for the frequent failure to mention it as one of the personnel of the firm. Almost from the beginning of time, capital has had labor to perform its manual work; but only since the days of absentee ownership and of widely distributed capital stock has it had management to do its thinking. Perhaps the explanation lies in the difficulty of recognizing managerial ability; it is vouched for by no academic degree, nor is it demonstrated by any specific manual or mental agility. Being a form of wisdom, it is beyond the ken of those whose horizon is bounded by mere knowledge. Or perhaps the basic reason is the ease with which the golden fruit of its effort may be confused by the unthinking with the results of chance or circumstance.

An article that will go a long way toward rescuing executive ability from its comparative obscurity has been published recently under the title, Management the Major Factor in All Industry. Written by John J. Raskob, chairman of the finance committee of the General Motors Corporation, it tells how this organization recognizes, esteems and rewards executive ability. A further account of this article will be found in the Notes and Reviews columns of this issue of THE JOURNAL.

September Council Meeting

A SESSION of the Council was held in New York City on Sept. 13, those attending being President Hunt; Second Vice-President Jones; Treasurer Whittelsey; and Councilors Winchester, Wooler and Veal; and J. W. White and E. W. Templin, who have been nominated to serve as Councilors for 1928.

The financial budget for 1927-1928 was approved. Two hundred and thirty-three applications for membership were approved. Twenty-nine transfers in grade of membership were made. The resignations of 13 members were accepted; and 4 reinstatements were approved.

C. F. Clarkson was appointed as the representative of the Society on the Main Committee of the American Engineering Standards Committee, as well as on the Executive Committee.

E. T. Jones, Arthur Nutt, Paul G. Zimmermann and E. P. Warner were appointed on the Board of Award of the Guggenheim Medal, to serve for 4 years, 3 years, 2 years and 1 year respectively.

Operation and Maintenance

MOTORCOACH-TIRE MAINTENANCE

Proper Air-Pressure and Care Fundamental to Satisfactory Service

Fundamentals of satisfactory motorcoach-tire performance are, according to L. G. Fairbank, (*a*) proper size to carry the load, (*b*) sufficient and constant air-pressure, and (*c*) proper care of the tires in service. Mr. Fairbank is manager of the truck and motorcoach-tire department of the Firestone Tire & Rubber Co. The following is an abstract of a paper he presented recently at a meeting of the American Electric Railway Association.

A recent check on about 150 motorcoach fleets distributed throughout the Country indicates decided progress during the last year in the care of tires, but it also indicates the waste of millions of tire-miles annually and the need for a standard tire-operating routine backed up by management.

Mr. Fairbank said:

> Do not kick or pound a tire to test the air pressure; use an air-pressure gage. Do not line-up wheels by sighting with the eye; use a wheel-alignment device. Do not guess at brake adjustment; use a brake-testing machine.

The following points were said by Mr. Fairbank to constitute desirable tire-maintenance practice:

(1) *Proper Size of Tire.*—Find the weight of the front and the rear of the motorcoach by actually weighing with full load. If the weight exceeds the carrying capacity of the tire, the operator cannot secure minimum tire-cost

(2) *Constant Air-Pressure.*—Check each tire for air pressure every 48 hr. If tire and tube are in good condition and properly inflated, and if the valve cap is securely applied, it is reasonable to expect that the tire will not lose air within 48 hr.

(3) *Compressed-Air Supply.*—Be sure the air compressor is of ample capacity and that plenty of air-lines, conveniently located, are provided. In larger operations it is not practical to move the vehicle to the air hose. Unless it is made easy to inflate the tires where the vehicles are parked, it is difficult to maintain constant air-pressure

(4) *Checking Air Pressure.*—Establish a system of checking air pressure regularly which will prevent employes from marking the record card "Air O.K." unless the pressure is actually checked with an air-pressure gage

(5) *Inside Dual-Tire Air-Valve.*—Be sure that the valve of the inside tire of dual tires can be reached easily with an air chuck. In many cases it is necessary to crawl under the vehicle or to remove the outside tire of the dual set to inflate the inner tire. In such case it is difficult to compel a service man to make this effort and the inner tire is usually neglected

(6) *Spare Wheels.*—A sufficient number of spare wheels to maintain service is essential; perhaps one spare wheel for every 12 wheels that are in operating service

(7) *Brakes and Wheel Alignment.*—Equipment and a regular routine for testing should be provided, as negligence will ruin tires

(8) *Tire-Service Room.*—Tube racks, a water tank for testing, tire tools, stock and the like require that the man in charge of tire service have space provided which he can call his own. An organized tire-service is impossible unless this is done

(9) *Education of Drivers.*—Regular class instruction regarding tire care, such as curb wear, use of brakes, treatment of flat tires, how valve-caps are applied and the like, should be given to drivers. Moving pictures, charts, and tire exhibits are available to help management to organize such instruction

(10) *Tire Repairs.*—The two essentials are to establish a system by which it can be ascertained what tires can be repaired profitably and to make certain that expert tire-repair work is done. The tire manufacturer can assist in this

(11) *Records.*—A system of records should be established so that every tire, every repair and every tire road-delay can be accounted for accurately. This affords means of locating trouble and correcting it

METHODS DESCRIBED IN THIS ISSUE

Papers presenting methods valuable to operation and maintenance engineers are printed elsewhere in this issue of THE JOURNAL. The one by A. W. Herrington on Using Truck-Operating Costs To Increase Delivery Efficiency treats the problem of developing some standardized method of recording fleet operating-costs so that they can be used for comparative purposes by citing a supposed company in the retail dairy business which has a fleet of 30 vehicles, assuming definite monetary values for the several factors constituting the total cost and analyzing the entire problem in a way to demonstrate the fundamental principles of a comprehensive system of accounting that will make evident all the information sought.

Another paper, by Lieut. W. C. Thee, Quartermaster Corps, U. S. A., on the Army System of Maintenance of Motor Transportation, describes why the Army, with its operating centers widely dispersed and its repair centers closely combined, is in a position to recommend its system of maintenance to commercial operators of motor-vehicles.

A third paper entitled The Wright Whirlwind Engine in Commercial Operation, by C. H. Biddlecombe, relates in detail the inspection and maintenance system used in connection with the flying operation of the engine, numerous features of which have a general application to motor-vehicles as well as specific application to aircraft.

TRANSPORTATION EQUIPMENT DESIGN

Motorcoach and Railway-Car Display at Cleveland Exhibition Shows Trends

Many new developments in connection with the automotive equipment used by electric street-railway operators were exhibited at the 46th Annual Convention of the American Electric Railway Association in Cleveland last month. A distinct tendency was shown toward the adaptation of the automotive type of drive to electric-car trucks by the display of several street-railway trucks driven by worm gears. In each case the trucks were mounted on antifriction bearings, of either the ball or the roller type, and in most of the cars internal expanding brakes mounted either on the inside of the wheel or on the axle displaced the conventional shoe-type brakes.

Trial is also being made of mounting the wheel tires on a peripheral rubber-insert or cushion to dampen noise. One such type of mounting consists of a completely enclosed pneumatic casing similar to a high-pressure-tire casing. This is of about 4 in. cross-section diameter and is designed to carry normally an air pressure of about 25 lb. per sq. in. A repre-

sentative of one company exhibiting street-car trucks stated that the company's experience so far indicates that cushioning with impregnated hard wood gives the best results. In all cases, however, the development of worm-drive anti-friction-bearing electric-railway trucks and cushion-tired wheels is in the purely experimental stage. The truck axles are of the conventional locomotive type. The worm-gear drives have a ratio of approximately 8 to 1 and give a maximum car speed of about 30 m.p.h.

Trend Toward Parlor-Car Motorcoach Type

In the electric-railway cars exhibited, a very distinct tendency in design toward the parlor-car motorcoach type of body construction was evident. This was revealed in sloping windshields with visors and wipers; flat roof-construction; passenger seats of the twin-type, usually upholstered in leather; and an individual seat for the motorman similar to the driver's seat in motorcoaches. Interiors of the cars shown were finished chiefly in light colors to give better light-distribution, while two and even three colors in bright tones were noticeable on the exteriors. One especially interesting exhibit was a 32-passenger six-wheel rail-car in which the forward two-wheel truck is rigid.

In the motorcoach exhibits, safety, comfort and refinement of design were noticeable, as were also two or three-color combinations with some striping and molding, especially for the parlor-car types. Lack of standardization of lamps and marker-light sizes, colors and locations was observable.

A Motorcoach for Private Touring

An interesting unit on exhibition was a coach intended for touring by a private owner. This was mounted on a twin-powerplant chassis, and the body dimensions were the same as those of the standard-size vehicle. It has a comfortable observation-parlor provided with large safety-plate-glass windows, and is finished in walnut and equipped with radio. Forward of this parlor is a combination dining and sleeping compartment with overhead cupboards and with facing double seats on one side and single seats on the other side. Ahead of this compartment are a pantry with closets, a galley with large sink, and a four-burner stove and water-heater. Across the aisle is a bath-room in which there are a dressing-chair and table, a shower, and other equipment. In the front end of the body is the driver's compartment, which is much like that in the usual motorcoach. In layout and construction this vehicle is very similar to a railroad private-car. The exhibit was of interest primarily as showing the possibilities for the development of a de luxe type of motorcoach for private touring.

RESEARCH AIDS MAINTENANCE

Manufacturer and University Laboratory Brought Together to Mutual Advantage

The simplest equipment, such as a tea-kettle, an apple, or a piece of raw rubber and a kitchen stove, has sufficed for much fundamental, though elementary, research. More elaborate and specialized equipment and more specifically trained personnel are almost invariably necessary for more refined investigation, even though it is purely experimental, if accurate results are to be obtained expeditiously; as, for instance, in the determination of the capacity and the limitations of the mechanisms of today. Commercial organizations often make investments of considerable sums in both men and machines to conduct investigations of their problems. At the same time, our colleges and universities have well-trained staffs and are provided with specialized equipment that frequently incorporates the results of much thought and mechanical ingenuity.

One of the functions of the Research Department of the Society is to serve as a connecting-link between the commercial organization wanting work performed and the college or university laboratory wanting a job to reduce the idle time of laboratory apparatus which represents a considerable investment, and to provide that contact with industry which is so necessary for both the faculty and the student if they are to be prepared to meet the needs of the industrial public they aim to serve. Attempts are made by the department to keep in touch with college and university research departments so that uptodate information on the equipment possessed shall be readily available. Industry also should be impressed with the thought that it is not without research resources so long as it can draw upon those of our institutions of learning.

An example of the functioning of the Research Department in making a connection between the work and the worker may be cited. Recently the Packard Electric Co. desired to have an investigation made of the importance from the maintenance standpoint of the use of good high-tension wiring in a motor-vehicle. Acting upon the recommendation of the department, it placed the investigation in the hands of H. M. Jacklin, assistant professor of automotive engineering at Ohio State University, who is well known to members of the Society for his work in developing an indicator for high-speed internal-combustion engines and for his researches on other automotive problems. Professor Jacklin conducted the tests in the automotive laboratory of the university, and the results are summarized briefly in an article entitled Shocking, which is reviewed in the Notes and Reviews columns of this issue of The Journal. This article, which incorporates scientifically derived data on the increase in power and in fuel economy to be achieved through sound high-tension wiring, should prove of interest to all engaged in maintaining motor-vehicles at the maximum efficiency for the public or for an industrial organization.

TO COOPERATE TO IMPROVE SERVICE

Executives of eight National organizations interested in automotive service met in New York City on Oct. 11 to consider the forming of an Automotive Service Council to coordinate service activities and cooperate in promoting better maintenance facilities for motor transportation in the combined interest of industry, trade, the user, and the public in general. The meeting was sponsored by the National Automobile Chamber of Commerce, which extended invitations to the following organizations:

American Automobile Association
Automotive Electric Association
Automotive Equipment Association
Motor and Accessory Manufacturers Association
National Automobile Dealers Association
National Standard Parts Association
Society of Automotive Engineers

In opening the meeting, Alfred Reeves, general manager of the National Automobile Chamber of Commerce, stated that the Chamber directors felt that something in the nature of the Motor-Vehicle Conference Committee, which coordinates the legislative activities of four National associations, might do a similar work for the service field, functioning as a committee to make studies and recommendations and carry on any work of an educational or advisory nature that would tend to raise the standard of practices and performance of maintenance work to the greater profit of the industry and trade and greater satisfaction to user and owner.

After an extensive discussion of what might be principal functions and specific activities of such a council, it was unanimously voted by those present that they approved in principle the forming of a council and recommended that an organization plan be outlined for submission to their various boards of directors.

Standardization Activities

NUMBERS FOR CRANKCASE OILS

They Should Be Used To Supplement Present "Light," "Medium" and "Heavy" Designation

Apropos of the Society's efforts to obtain cooperation of the automobile manufacturers and the oil companies toward more general use of the S.A.E. Lubricating-Oil Numbering-System for specifying lubricants for motor-cars, the following statement was prepared by one of the members of the Lubricants Division of the S.A.E. Standards Committee for distribution among the engineers of his company. It is of considerable interest.

At the last meeting of the S.A.E. Lubricants Division much favorable sentiment was expressed regarding the S.A.E. system of viscosity numbers and it was voted to retain this system as it stands and to determine a suitable means for putting it into wider use.

In the past, the refiners, while not enthusiastic about adding the S.A.E. Viscosity Number to their brand names, have agreed to use these numbers if and when they are specified by the automotive engineers. On the other hand, the automotive engineers have always agreed to consider these matters if and when the refiners actually use the S.A.E. Numbers.

The S.A.E. Viscosity Numbers cover certain viscosity ranges and are simply a means of defining the terms "light," "medium" and "heavy." While it might be desirable to use these terms instead of S.A.E. Viscosity Numbers, this is impossible due to the fact that all of the refiners do not agree on the meaning of "light," "medium" and "heavy." For example, one company markets an oil under the term "light," while another company markets oil of the same viscosity under the term "heavy"; one company markets an automobile oil under a certain trade-name as "medium" and the same company also markets automobile oil of the same viscosity, but under another trade-name, as "heavy." Another difficulty is the fact that a heavy turbine-oil is a "medium" automobile-oil and a "light" truck or tractor oil; but it may be the same oil from the same container.

The automotive engineer wishes to recommend oils of certain viscosities. Since he cannot use the terms "light," "medium," or "heavy" at present, due to the confusion which exists as to the meaning of these terms, and, since the refiners will not change their practice in regard to the use of the names, the automotive engineer must specify oils in terms of viscosity. A National system which is to cover oils distributed over the entire Country and refined from all types of crude must give the least difference at high operating-temperatures and at low cranking-temperatures for all oils. To meet these requirements, the present S.A.E. system specifies the viscosity at 130 deg. fahr. for the lighter oils and at 210 deg. fahr. for the heavier oils.

Several of the large refiners are now marking their oils with the S.A.E. Viscosity Numbers in addition to their trade names and one of the large automobile companies is using this system in its instruction book. The wording is as follows.

> For correct engine lubrication a high-grade, well-refined oil is essential. As a guide to the proper viscosity or body of oil for summer and winter conditions, which vary for different territories, the lubrication charts of the reputable oil companies should be consulted. In general, an oil having the body of S.A.E. Viscosity Number 30 is recommended for summer use and for winter use except where zero or below-zero temperatures are encountered. For the latter condition, an oil with a low cold-test and with a body of S.A.E. Viscosity Number 20 or 30 is recommended.

It is suggested that the automotive engineers of all companies specify engine oils in instruction books in a similar manner, instead of using the obsolete terms "light," "medium," or "heavy," or an approved list which, from its nature, cannot be complete and is discriminatory in character.

This is one of the instances of the practical interest that is being exhibited in this subject, and the many expressions of approval by engineers from both oil-refining companies and automobile manufacturers are indicative of the need for the use of such a system.

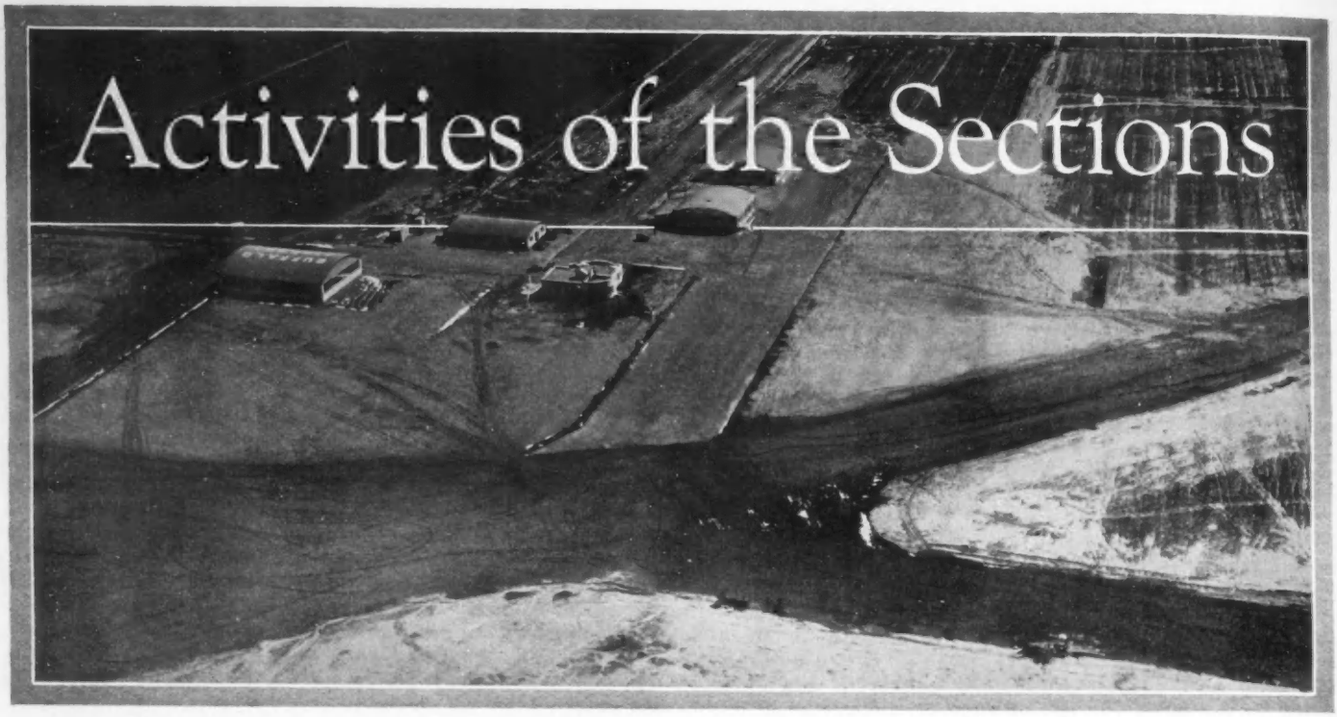
AIRPLANE INSTRUMENT MOUNTINGS

Subdivision of the Standards Committee Formulating Preliminary Report

The Airplane Instrument-Mounting Subdivision of the Aeronautic Division of the Standards Committee held its first meeting on Oct. 17 in the offices of the Society. Archibald Black, chairman; C. H. Colvin; Lieut. T. C. Lonnquest, U. S. N., and Standards Manager R. S. Burnett were present. The suggested program for standardization made previously by Lieut. M. F. Schoeffel, U. S. N., was discussed in detail and included such items as instrument-case dimensions, tubing connections, dials and pointers for airspeed indicators, altimeters, tachometers and other airplane instruments.

It was felt that at least some degree of standardization can be had for the mounting dimensions and tubing connections of instruments in two or three established sizes, but that some of the instruments that are at present somewhat special should not be included in the program. It was thought also that the vertical-scale type might be listed to give the airplane designer data to work with in laying-out his instrument-boards.

It was decided to send to the members of the Subdivision a tabulation of dimensions to be submitted by Mr. Colvin, which is to be studied with a view to developing it into a definite standard. An important point discussed in connection with the project was that whatever standard may be developed at this time should conform as much as possible to present accepted practice, but that, as the art develops and changes in the future, the standard should be revised to meet new conditions.



IMPORTANT FEATURES OF UPKEEP

Southern California Section Studies Inspection and Maintenance Methods

An intensive effort on the part of the Southern California Section resulted in a crowded program replete with interest to operators of motor-vehicles at the meeting held in the Los Angeles City Club on Sept. 30. An address by Coker F. Clarkson, secretary and general manager of the Society, three papers on motor-vehicle inspection and a paper on the inspection and maintenance of axles were included. A representative attendance of 162 members and guests was recorded. Ethelbert Favary, chairman of the Section, presided.

After commending the work of the Section and the effectiveness of Mr. Favary's efforts as its chairman, Mr. Clarkson outlined the plan of the Society regarding the furtherance of progress in operation and maintenance methods, a plan devised to benefit the many hundreds of members throughout the Country who are directly interested in this important and very comprehensive subject. He said in part that the Society endeavors to function as a living force in automotive engineering. Its endeavor is to anticipate important new developments, to secure statements with regard to them by authorities, and also to obtain and disseminate comprehensive statements on subjects of broad interest even though the subjects be old. To this end, the Operation and Maintenance Committee of the Society has been made as nationally representative as is possible, and subdivisions of the main committee have been organized.

Mr. Clarkson stated also that, of the subcommittees, the Accounting Committee is fundamentally important. The large companies throughout the Country have cooperated by describing their methods of operation and how they approach the accounting problem. He mentioned two schools of thought in regard to accounting; one comprising the group under Government regulation due to the nature of their other operations. For instance, this group may feel that the automotive accounting problem should be worked out along lines similar to the methods of railroad accounting. The other group believes that the automotive accounting-problem is a new and different one that should be solved in its own way. The nomenclature subcommittee is also a basic feature in that a satisfactory accounting system cannot be assured until certain terms have been defined satisfactorily. There are also a subcommittee on regulations and a committee on education in general. An endeavor is being made to interlock the work of the Operation and Maintenance Committee with that of the other major elements of the Society; that is, various members of the committee are designated as representatives who will make contact with the various departments of the Society. In this manner, Mr. Clarkson believes, unparalleled cooperative work on these matters will be accomplished.

Details of Inspection Methods

Desirable inspection methods were outlined by three speakers, who described the practice of their several companies from the viewpoint of maintenance. The speakers were P. H. Ducker, of the Southern California Edison Co.; J. L. Ferguson, of William E. Bush, Inc.; and F. C. Patton, of the Los Angeles Motorbus Co.

Mr. Ducker said in part that the two classifications of fleet operation are the one in which all the equipment is housed at one location and that in which the fleet is divided into sections and located in various parts of the territory served. In the first classification he said that it is much the best plan to employ a first-class inspector who also has a knowledge of the symptoms of certain troubles and who can advise mechanics how to proceed. His paper was confined to the procedure and duties of such an inspector.

Maintenance and repairs on the better grade of passenger-cars was the phase discussed by Mr. Ferguson. In this class of work the method used in accepting repair work and in diagnosing trouble is perhaps less methodical than might otherwise be the case. He emphasized the importance of the first relations a service man may have with a customer, and the ability the service man must possess in comprehending first the customer's viewpoint. Determination of whether the customer is correct in his estimate of the cause of trouble is a matter for subsequent analysis. One of the most successful means of diagnosing trouble is to drive the car as nearly as possible under the same speed and road conditions as those under which the customer experiences the trouble he reports. The speaker then went on to enumerate some of the major troubles reported by customers and to suggest proper means of determining the causes.

With regard to the inspection of motorcoaches, F. C. Patton said that the schedule which such vehicles are required to maintain makes a careful inspection imperative to prevent, so far as possible, interruptions to service that are due to

failure on the road. Since the schedule requires that a certain number of vehicles must operate, the maintenance department must keep that number of units in operating condition and must also predetermine the probable mechanical failures of the various units so that needed repairs and replacements can be made before actual failure occurs. He then described briefly the system used by the company he represents in maintaining a fleet of 40 double-deck and 46 single-deck motorcoaches, dividing the inspection into the three major groups: Daily inspection and adjustment, regular inspection for oil and grease each 750 miles, and a general inspection each 2250 miles.

Maintaining Motor-Truck Axles

Front-axle inspection, worm-drive rear-axle inspection, and lubrication were the main divisions of the paper by P. W. Sloan and C. H. Jacobsen, service managers respectively of the Timken Detroit Axle Co. and of the Moreland Motor Truck Co. Inspection of the front axle should be made after each 5000 miles of operation. At this time the inspection should include also the hubs, the steering-knuckle, the steering connections and the steering cross-tube, as well as their related minor parts. The complete front axle should be removed from the vehicle and dismantled after each 50,000 miles. Details of the worm-drive rear-axle inspection were also presented. In reference to lubrication it was recommended that charts be devised that will assist the men responsible for oiling and greasing to make certain that all points requiring lubrication be lubricated after having been in operation for a stated number of miles. The men responsible also should be trained to make certain that the oil and grease actually reach their proper destination. This includes a test to determine whether the lubricating channel is clogged, or whether the lubricant oozes out.

Major Points of the Discussion

A feature of front-axle inspection which is neglected in many instances is the repair of bent tie-rods. The usual remedy is simply to adjust the tie-rod to produce a proper amount of toe-in. Attention was called to the need of some routine method of redetermining the exact position of the pivots of the tie-rod, which is in a direct line between the front-wheel king-pin and the center of the rear axle.

Other features included remarks by Mr. Patton describing the practice of servicing the vehicles of the fleet mentioned in his paper; and remarks by others on the subjects of details of lubrication practice and the design of automotive equipment with regard to accessibility that will facilitate repairs.

NATIONAL MEETING PAPER RESUME

Maintenance and Operation the Subject of Wood's Address in San Francisco

A summary of his paper on Maintenance and Operation, which was to be presented at the Transportation Meeting of the Society in Chicago the last week in October, by Edwin C. Wood, chairman of the West Coast Subcommittee of the Operation and Maintenance Committee and superintendent of transportation and general shops of the Pacific Gas & Electric Co., was the subject of the meeting of the Northern California Section on Oct. 13. The meeting was held in the new club rooms of the Engineers Building, San Francisco, and was preceded by a members' dinner at 6:30 p. m.

The occasion afforded an opportunity for the Golden Gate members to hear the high points of Mr. Wood's paper in advance of the membership at large who attended the National meeting and to discuss the problems of fleet operators on the Pacific Coast as set forth by the author. Interesting entertainment had been arranged for by J. Lepkos, chairman of the entertainment committee of the Section.

When he visited the members of the Section in San Francisco in September, General Manager Clarkson found the Northern California Section to be in a thriving condition. Great earnestness is shown by the members in the solution of automotive engineering problems peculiar more particularly to the Pacific Coast. The program of meetings for this season has been outlined in a way that should be very helpful, the first sessions for the year having already been held. California is a world by itself, so to speak, and it can, and it is thoroughly expected will, be very helpful in the solution, not only of Pacific Coast automotive engineering problems, but of National and international problems as well.

AIRPORT PLANNING AND NEEDS

MacCracken Tells Metropolitan Section of Status in New York City

Mutual needs of airports by cities and by aviation, if the latter is not to be hindered in development, and the requirements and facilities needed by airports themselves if they are properly to serve commercial aviation, were expounded and debated at the October meeting of the Metropolitan Section. This meeting was tied in happily with the Aeronautic Meeting of the Society by the making of arrangements to hold it at the Waldorf-Astoria Hotel in New York City the night of Oct. 20 following the afternoon final session of the National meeting.

The Section was highly fortunate in securing for its first speaker William P. MacCracken, Jr., assistant secretary of commerce for aeronautics, who was announced by Chairman Charles H. Colvin after E. F. Lowe, Section chairman, had extended a brief welcome to the members and guests of the National Society.

Instead of delivering a prepared address on the subject, a Commercial Airport for New York, which had been assigned to him, Secretary MacCracken stated that the situation in the Metropolitan district is undergoing such rapid changes that it would be impossible to prepare remarks in advance. He gratified the audience much better by stating some of the facts developed at an afternoon meeting on the same day of the Executive Committee of the Fact Finding Committee of the Metropolitan district, of which he is chairman, and which is studying the entire problem of the selection, construction and operation of a suitable municipal airport for the City of New York.

Seventy Possible Metropolitan Airport Sites

Seventy possible sites for such an airport have been submitted to the Committee, and these have been investigated and inspected both on the ground and from the air. It is hoped, he said, that within a reasonable time a report can be brought forth by the Committee which will present the true situation with reference to what is available for such an airport and the best means by which to acquire and develop it. The Fact Finding Committee is composed of representatives from both New York City and northern New Jersey who, in general, represent the business interests of the two communities. Work of the Committee is divided among subcommittees on locations, valuations, engineering, and ways and means, and an executive committee composed of the four chairmen of the subcommittees, the chairman of the executive committee and a general vice-chairman.

The Metropolitan area presents some particularly complicated conditions, such as the lack of large open spaces, the divided authority between the States of New York and New Jersey, the division of the local government among five boroughs in Greater New York, and the differences of opinion that are engendered by these conditions. Notwithstanding these and other difficulties, Secretary MacCracken said that he hopes that the engineering fraternity and the entire business and commercial interests of the community will get behind any reasonable program that may be evolved and see to it that the great Metropolitan area, the heart of the commercial life of this Country, is adequately served by one or more commercial airports, the lack of which is stifling commercial aviation throughout the United States.

Berlin's Airport Wins Public Support

The speaker cited an experience of his own not long ago when he flew from the City of Washington to Hadley Field, New Brunswick, N. J., in 1 hr. 50 min. and spent exactly the same time in reaching Manhattan in a taxicab from Hadley Field to Newark, N. J., and a Hudson-Manhattan tube train to the Pennsylvania Station in New York City. We cannot expect aviation to develop in this Country as we want it to develop with such a situation existing with reference to airports in the greatest commercial city in the Country, he said. By contrast with this situation in the greatest city in America, Secretary MacCracken spoke of the important influence that the airport in Berlin has had on the development of commercial aviation in Germany. So far as location is concerned, the Berlin airport is one of the best in the world, and it has attracted the interest and attention of the German people because it is in the heart of their capital where they can reach it in 10 or 15 min. to see the airplanes arrive and depart and can dine and listen to music. In short, it is a recreation center as well as the center of air-commerce operations. The result is that the airlines have the united support of the public, and this has grown to such an extent that in some cases as much as 70 per cent of the operating revenue has come from the taxpayers in the form of direct subsidies. The best way to sell the public on commercial aviation, declared the speaker, is to provide an airport that the people can visit regularly and be glad to do so. Certainly, New York City, with all its wealth and millions of people, can afford to pay the price that would be necessary to accomplish this, and in doing so they would be serving the commercial interests, fostering prosperity, and at the same time strengthening the National security.

Business Leaders Aware of Aviation's Influence

From business leaders of many cities in many States, in talking with whom he has spent most of his waking hours during the last 3 months, William E. Arthur, of New York City, said he brought the message that the villages, towns and cities of America are vitally aware of the paramount influence that aviation will have on the future of their growth. The business world is speaking now and it is the industrial interests entering this field that are to develop aviation as an important and workable unit in the Country's transportation system. The business world is seeing aviation as a profitable investment. The progressive community is beginning to realize that a well-equipped airport will bring it greater contact with the Country and greater commercial and industrial development. The future city without an airport will be in the class with a coastal city without a harbor. Every city and town should see to it that a suitable area, as centrally located as possible, is set aside for a future landing-field.

Factors of equal importance in choosing the site and planning the airport are drainage; transportation; communication by telephone, telegraph and radio; building arrangement, construction and equipment; and lighting systems. The airport should be of sufficient size to permit efficient operation of all types of commercial airplane and should be easily accessible and careful planning should be directed to unlimited future expansion. Obstructions on adjoining property should be avoided, and trees and telephone wires should be removed for a distance of at least 500 ft. from the borders of the field. No high hills should be close enough to block the approach. The ground should be firm and substantially level.

Design and Cost of Airports

One of the most approved designs is an airport of approximately rectangular shape from 3000 to 4000 ft. long and 2500 to 3000 ft. on the shorter sides. Runways extend from the corners and are approximately 3000 ft. long and 300 ft. wide. All buildings are erected in a triangle in one angle formed by the intersection of the runways. The main runways should extend in the direction of the prevailing wind. The best runway surface is of sod on top of crushed stone or gravel.

Buildings should include a passenger station, with telephone, telegraph and radio rooms, baggage room, meterological station, and dispatching office; a field post-office and, in border cities, a customs office; a separate freight and express building; and necessary hangars and motor-vehicle garages.

All necessary lighting of the airport for safe night-flying should be provided.

The cost of an airport or a landing-field varies widely; some have cost $15,000 and others more than $1,000,000. The municipal airport at Buffalo, which he designed, said Mr. Arthur, cost $500,000. On the day upon which he gave his address, he was working on a field in Connecticut that will have an area of 210 acres and cost $115,000. It is to be equipped for both landplane and seaplane facilities. A few days previously he was in Northampton, Mass., which has selected a field of 352 acres, which is to have one runway 6700 ft. long and another 5850 ft. long, with a 1200-ft.-diameter landing circle at the intersection for light airplanes. Cleveland has a 700-acre field that cost in the neighborhood of $1,250,000.

On his trip in New England during the week, said Mr. Arthur, he found several cities along the coast that are planning airports so situated as to provide facilities for both seaplanes and landplanes, as recommended by Assistant Secretary of the Navy Warner. Within the next 6 months, he believes, at least five airports between New York City and Nova Scotia will have both water and land facilities for air travel.

Capital and Patronage Prime Needs

Gen. J. F. O'Ryan, president of the Colonial Air Transport, Inc., and the third speaker on the program, had no written address but gave a most interesting talk on practical operation and the present need for developing an understanding by the business men and industries of the Country that it is to their interest to supply capital and to develop traffic for commercial airlines. We have dependable engines and planes, and airports are well under way. On his own line, the mail load increased from 10 or 12 lb. per day a year ago to about 110 lb. per day at present; and the major part of the increase came from business concerns that have been using the Air Mail from the start, because they found that it met some of their needs and increased their business. Air transport is here, he said, and from now on its progress will be steady. The public, however, is not air-minded, and city officials and business men know little about the requirements for a suitable airport.

As experience shows that political subdivisions rarely produce the same measure of efficiency as private enterprise, General O'Ryan expressed the opinion that in many of the smaller cities and towns the airports will be developed by private citizens.

A second stage of airport development has been undertaken by the American Airports Corporation, of New York City, he said, whose purpose is to take over a string of airports for operation on the chain-store plan. The idea is to tie together the system of services, such as garaging and servicing aircraft, restaurant facilities, and communication, under competent managements, so that all the airports shall be adequately served.

A Plea for Broader Vision

At the conclusion of the addresses by the speakers on the program, John E. Nolen was given an opportunity to conclude a paper on Airport Planning which lack of time at the concluding session of the Society's National Aeronautic Meeting prevented his finishing in the afternoon. The speaker made a most urgent plea for broad vision of the future of air commerce and the need of planning for the expansion of a generation. Instead of thinking of one airport for New York City, we should develop 7 or 17 of the possible 70 sites under consideration. We need both publicly and privately owned ports. We should draw upon the experience of men in other transportation fields, such as the railroads, the waterways and the highways, and upon legal

talent for advice with regard to land and zoning laws and the like. In conclusion, he showed a design of a model airport of 160 acres that had been projected as a community development.

In the discussion that followed there were pleas for the temporary use of Governor's Island as a Metropolitan airport pending the development of a permanent municipal airport. and equally vigorous objections to it. The latter were voiced by Secretary Warner, C. H. Biddlecombe and by Mr. Merrill, of the Curtiss Aeroplane & Motor Co. The objections were chiefly on account of atmospheric conditions over the harbor and the limited size of the island. Mr. Warner disparaged the inclination of some people to hold back from large-airport development in the belief that progress in airplane engineering soon will make possible the landing and taking-off from roofs and very small fields. On the contrary, while airplanes can land and take-off at lower speeds than a few years ago, the commercial loads are increasing fast and, actually, longer runways are required. Larger ships will be built and will have multiple engines, and operations will be planned with reference almost solely to terminal airports.

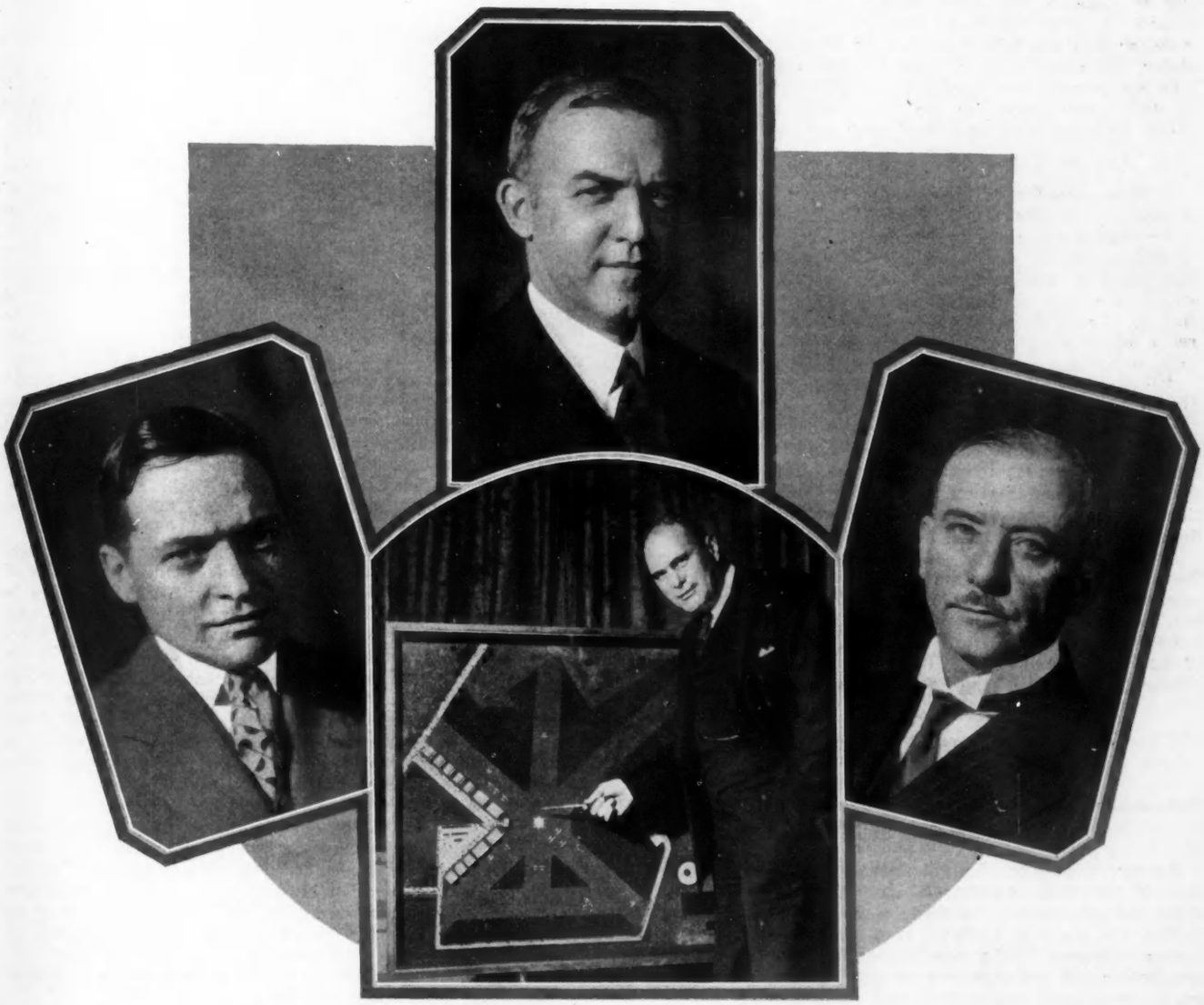
FLYING FEATS NARRATED

Oceanic Flights and Prizes Now Offered Described After Boston Airport Visit

For its October meeting 40 members of the New England Section visited the Boston Airport on Wednesday afternoon, Oct. 5. After a dinner at the Engineers' Club, Walter F. Eade, of the aeronautical research department, Massachusetts Institute of Technology, addressed about 75 members and guests, discussing chiefly the various transoceanic flights of the year, including those that have been proposed or attempted as well as those that have been accomplished, and the Schneider Cup Race.

He said that there has been continuous progress from the time, 20 years ago, when Farman established a world's record with a flight of 311 yd., to the present record of 3790 miles' continuous flight.

Prizes of considerable amounts have been offered for six different flights. Col. Charles A. Lindbergh won the prize of $25,000 for a New York City-to-Paris flight and Art C.



CHAIRMAN AND SPEAKERS AT THE METROPOLITAN-SECTION MEETING

C. H. Colvin, of the Pioneer Instrument Co. (Left), Who Presided at the Session, and Hon. William P. MacCracken, Jr. (Center), Assistant Secretary of the Department of Commerce for Aeronautics; Gen. J. F. O'Ryan, of the Colonial Air Transport (Right), and William E. Arthur (Lower Center), Who Discussed Airports

Goebel won the Dole prize of the same amount in the flight from San Francisco to Honolulu. The flights of Clarence Chamberlin and Commander Richard E. Byrd were technical flights, the one establishing the long-distance record and the other affording valuable information with regard to weather conditions and radio operation over water. The Hawaiian flight of the Army airplane was made before the time specified for the Dole prize flight.

Prizes Still Open for Competition

In addition to the prizes that have been awarded, a prize of $10,000 has been offered for a flight from New York City to Bermuda and return; one of $50,000 for a flight from San Francisco to Honolulu and return; one of $25,000 for a flight from Dallas, Tex., to Hong Kong; and a like prize for a flight from Seattle to Tokio. The first of these flights probably will be accomplished in the near future. That from San Francisco to Honolulu and return is more difficult than might appear, because of head winds during the return trip which would increase the effective distance by about 400 miles. Because of the necessity of making stops at small islands in the Pacific, attempts at the two proposed Asiatic flights would seem to be suicidal.

Mr. Eade said that it is impossible for a flying boat, even one so large as the Navy PN-10 weighing 21,000 lb. fully loaded, to leave the water once it is down in a heavy sea. Another airplane attempted to take off from behind a breakwater, but when it broke from the water it would still crash into the waves, resulting in the engines being displaced 12 in. from their bases. In the PN-10 hull it is said that the rivets were loosened by impact with the waves.

Planes, Engines and Accessories Pictured

A large number of slides were shown, including photographs of the Packard-X, Pratt & Whitney, Caminez, and other engines; of a carbureter heater like that used on Lindbergh's plane; of inertia and electrical starters; and a General Electric supercharger. Among the complete airplanes shown were the original Wright plane, a new Canard, the Argosy, the 1926 Macchi Schneider-Cup racer, the Kirkham racer which was intended for the Schneider Cup Race this year, and a number of British airplanes.

The discussion included questions as to the relative advantage of air-cooled and water-cooled engines, Mr. Eade favoring the former because it is lighter than the water-cooled engine with its radiator and connections. Further discussion related to the earth inductor compass, structural details of the Packard-X engine and the preparations for the navigation of Colonel Lindbergh's and other recent transoceanic flights.

Attention was called to the great increase in attendance at Section meetings on aeronautical subjects due to the greater interest in aviation. At a meeting of the New England Section later this year it is expected that airplane engines will be discussed by Lieut. Alford J. Williams and representatives of the Packard and Pratt & Whitney companies. Frank E. H. Johnson, chairman of the Section, presided at the meeting.

TIRE MANUFACTURE STUDIED

Milwaukee Section Hears of Trends and Sees Night Production in Plant

Taking advantage of night operation in the Federal division of the Fisk Rubber Co., the Milwaukee Section was given the opportunity to make a trip through the Federal Rubber Co. plant in Cudahy, Wis., to observe tire-manufacturing processes. This was the regular October Meeting of the Section but the date was advanced to Sept. 30 so that it might occur while night work was in progress.

About 60 members of the Section were guests of the Rubber Company at a splendid dinner, which was served early in the evening under the direction of E. E. Derth, general superintendent, assisted by W. A. Miller, H. B. Soulen and L. J. D. Healy, all of the Federal plant. After the dinner came a business session, followed by the reading of a paper on Recent Trends in Automobile Tire Construction, by Mr. Healy, technical superintendent of the Federal division. Then a large number of lantern slides were projected on the screen to show the growth and handling of raw rubber, the growth of cotton and production of fabric and the laboratory equipment and manufacturing processes of a tire factory.

The party was then divided up into groups of about five individuals, each accompanied by a competent guide, and spent the remainder of the evening in watching the work done in the casing-production department of the Federal Rubber Co. factory.

During the business session it was announced that plans had been made for an extremely active and interesting series of Section events throughout the year. At the November meeting there will be a paper by Edward T. Jones, chief powerplant engineer of the Wright Aeronautical Corporation, of Paterson, N. J.

VIEW OF AUTOMOTIVE WORLD

Detroit Section Learns of Conditions Here and Abroad from Hunt and Gale

Business Conditions in China, with particular reference to the development of the automobile market in that country, described by Prof. Esson M. Gale, lecturer at the University of Michigan, and some pertinent suggestions for the future improvement of the automobile here at home, under the title, Today's Demand on the Automotive Engineer, made by President J. H. Hunt, of the Society, served to draw a large attendance to the first meeting of the present season of the Detroit Section, held at the Book-Cadillac Hotel, on Oct. 10. In the words of the chairman, Walter Fishleigh, these topics were selected "to put on a general view of the automotive world." More than 300 members and their guests attended the meeting, of whom 215 were present at the dinner that preceded it. It was announced that during the coming winter meetings of the Detroit Section will be held monthly instead of semi-monthly, as was the case last year.

Although China is one-third larger than the United States and has a population four times as great, only 19,000 motorcars are in use, declared Professor Gale. Of the 4500 cars imported into China in 1926, 3332 came from the United States. A total of 23,000 cars was exported from the United States last August. Statistics show, said Professor Gale, that there is one automobile for every 66 persons in the world; in China, there is one for every 23,000.

Transportation in China depends mainly on the river system and on the 225,000 miles of canals. Only 7000 miles of railroad exist in China as compared with 265,000 miles in the United States. The railroads are practically long-haul trunk lines and are laid out so as to form a T. No interurban electric lines have been built. The wheelbarrow is the vehicle most in use, the wages of the coolies being $0.30 for a 12 to 14-hr. day. The Chinese are excellent chauffeurs but are lacking in mechanical ability. If a car breaks down, they hit it with a hammer, on the principle of shaking a watch to start the works. The wealth per capita in China is low, but the country has many capitalists, who, because of the unsettled conditions, have put their money into foreign banks. Modern roads exist only in the vicinity of the treaty ports, but in other sections are very primitive. For that reason, light cars with short wheelbase are the most useful and economical. Cars can be used only on level roads and in dry weather; in the winter, the frozen rivers are used as roadways. In Professor Gale's opinion, the construction of roads would be simple with labor so cheap. He believes that, when the Chinese discover the profits to be made from motorcar operation, good roads will be developed.

Hunt Discusses Saturation-Point

President Hunt described the saturation-point, as applied to the automobile business, as the point at which, when a new car is sold, another car must be relegated to the junk

pile. On the basis of the rate of scrapping cars, automobile saturation has reached only the half-way point. An average of one car per family is approaching.

When heat is applied to a chemical solution, the saturation-point can be raised slightly, but when the solution cools, crystals will be precipitated. Effective advertising, he said, has a similar effect on motor-car sales. Heretofore, advertising has been devoted mainly to the details of the construction of the car, but, now that the construction of the chassis of each car has become practically standardized, other features, such as appearance, are stressed. Parts are supposed to outlast the life of the car, but the makers of some parts, such as spark-plugs, recommend their being changed each year. The average life of a car has been increased 30 per cent since the war. This affects the rate at which new cars can be built and necessitates their being made more desirable so that owners will be induced to discard old cars before they have outlived their usefulness. Intense competition is caused by the fact that factories can produce 60 per cent more cars than the public is buying, consequently new ways must be found of creating a demand for a particular car. Increase of sales can be made only at the expense of competitors. Appearance is becoming more important and is believed to be the cause of the shifting of public favor from certain makes of car to certain others. The reputation of the manufacturer is also more important than it was several years ago and affects the opportunities of new companies.

The immense investment in tools and equipment produces pressure against the risk of making ill-considered changes. When changes are made, they must follow established lines, and must be made in the most efficient way so that too many units of the factory will not be affected at one time. Mr. Hunt believes that the prosperity of the automotive industry has been due, not so much to what engineers have done, as to other factors, such as good roads, cheap fuel, improvements in tires, and the like. Even though the Chinese people were as wealthy as Americans, the market in China would not equal the American market because of the lack of roads there. The country is not physically equipped to use the cars.

Automotive and Electrical Industries Compared

President Hunt compared the development of the automotive industry with that of the electrical-machinery industry. Early electrical plants produced machines of great diversity of design, but these have gradually become standardized and the plants have been combined. The early advertising of differences in structural details has disappeared. Recent discussion of the merits of different types of automobile brakes was compared with that which formerly took place concerning the advantages and disadvantages of direct-current and alternating-current machinery.

Twenty years ago the saturation-point in the electrical machinery industry, not of ultimate use but as determined by the technical situation at the time and by the commercial condition of the Country, seemed approaching; but in 20 years great improvements have been made in the efficiency of the incandescent lamp, for example. The first lamp of 2.5 watts had difficulty in competing with gas, but research found ways of increasing the temperature of the filament and other changes followed. The types and efficiency of prime movers also changed.

The automotive industry, in the opinion of President Hunt, is now nearer the ultimate quantitative use of its products than was the electrical industry at that time. Its position is similar in many respects to that of the carbon lamp at the time the metal filament was introduced. Recent improvements in the automotive industry include the use of better fuels and better knowledge of their use and a gain in the performance and efficiency of internal-combustion engines by increasing the compression, which is like the increase in the temperature of the lamp.

Future improvement of the automobile, continued Mr. Hunt, will lie along the line of improving the fundamental efficiency of its parts. The changes that remain to be made are small relatively but are highly important commercially. They may not be much when measured by the laboratory, but will be important in the eyes of the user of the car. The cost of repairs is much too high. No adjustment in any part in 10,000 miles should be the objective sought. Real advance

Some of Those Who Dined at the Book-Cadillac Hotel and Attended the Opening Meeting of the Detroit Section on Oct. 10 to Hear Addresses by President Hunt and Professor Gale

will be made when engineers devote themselves to such a problem. The rest is dependent on the factory and the inspection department.

ARMY MOTOR EQUIPMENT

Distinguished Speakers and Guests Tell Washington Section about Tanks and Tractors

Preliminary views and descriptions of the latest developments in tanks, tractors, trucks and other motor equipment of the Army were given by Army men at the meeting of the Washington Section on the night of Oct. 5, at the Racquet Club, City of Washington, as a survey of some of the ordnance equipment that the members of the Section were to see in action at Aberdeen Proving Ground during the demonstrations on Oct. 6, of which a news account is given elsewhere in this issue of THE JOURNAL.

Distinguished guests in attendance at the Section meeting were Hon. F. Trubee Davison, assistant secretary of war for aeronautics; Hon. Benedict Crowell, president of the Army Ordnance Association; Major L. H. Campbell, U. S. A., chief of the automotive section of the ordnance office of the War Department; and Capt. L. R. Lohr, executive secretary of the Society of Military Engineers. A. W. Herrington, chairman of the Section, presided.

Secretary Davison, when asked to make an address, stated that the aspect of the demonstrations at Aberdeen in which he was most interested is the anti-aircraft work and that, in his opinion, the anti-aircraft men are prone to deceive themselves as to the effectiveness of the guns and the aircraft pilots to scoff too much at their effectiveness. The Government, he thought, should make every legitimate effort to develop anti-aircraft fire to the maximum. A big development has been made since the war and promises much for the future. If vital points can be protected with anti-aircraft guns, the air force can devote its energies to other purposes. He said that it is especially interesting and encouraging to see so many civilians visit the Army Ordnance Association's demonstrations at Aberdeen each year, as this means that the public will come closer to the technical developments that are being made in the Army ordnance.

LATEST DEVELOPMENTS IN AUTOMOTIVE EQUIPMENT

Three dozen lantern slides of automotive equipment now used by the Army were shown and the tanks, tractors, trucks, trailers and officers' cars were described briefly by Major Campbell, of the Ordnance Department, which provides the Army with automotive vehicles that operate principally off of the highways.

In his address he endeavored to carry his hearers, in a very brief review, from the time the Ordnance Department entered the automotive field down to the present time, stating that this is a comparatively new field for the department, which began actively in 1917 to conduct its own development work with the assistance of the outside industry. Theretofore, it had bought a few commercial tractors which had been given a trial in Texas. It is his own belief, he said, that the next war will create a demand for a high-speed tractor and that a type of 2½-ton artillery tractor, which he showed, will be built in quantity. Another tractor built at the Rock Island Arsenal and designed for operation on the roads on rubber-tired wheels, and the substitution therefor of crawler treads for operation off the highways, is driven by a 100-hp. engine and has a speed of 10 m.p.h. This crawler tractor is very acceptable on the whole, and will haul an 155-mm. howitzer or a 4.7-in. gun. The policy of the Ordnance Department, for the immediate future, is to go into the commercial market for its supply of commercial tractors in time of war, said Major Campbell, which has the advantage of enabling the Army to purchase large numbers quickly and also to obtain operators who are familiar with their use. For this reason, after giving it very exhaustive tests, the department has adopted the Caterpillar tractor as the standard to be issued to troops. The enormous requirements of such tractors in the event of war makes it obvious that they cannot be met at once. The speaker recalled that in the late war 28,000 5-ton tractors were required to meet the plans.

A very interesting development, of which another slide was shown, is a tractor mounting a French-75 gun that can be fired in 1½ min. after reaching a firing point. This has a speed of 15 m.p.h.

Several other automotive gun-carriages were shown, including the largest, driven by a 180-hp. Sterling engine and mounting a 155-mm. gun weighing 46,000 lb. complete, or an 8-in. howitzer. There are two of these at the Aberdeen Proving Ground built in 1921 by the Holt Caterpillar Co. and they have given very satisfactory performance.

TANKS HAVE BEEN GREATLY IMPROVED

With reference to tanks of which a number of slides were shown, Major Campbell said that a pilot model of a little tank which the Ordnance Department feels is the most wonderful of its kind has just been finished but information about it has not yet been released for publication. As a result of experience with various types of tank, the department laid down and has built two medium-size 23-ton tanks with crawler-type treads and with a double turret protected by 1-in. armor. These are the latest development in large-size tanks and are driven by engines designed and built commercially for the Army by the Packard Motor Car Co.

A vehicle that the speaker called "a pretty good little mud-hog" is a four-wheel-drive balloon-tired power cart weighing 750 lb. and having a capacity of 450 lb. It is driven by an air-cooled motorcycle engine and is articulated between the front and rear axles in both vertical and horizontal planes.

In an attempt to supplant the horse's reconnaisance work, the department now uses a Ford, a Chevrolet or other light car equipped with large balloon tires and bucket seats and with the weight reduced as much as possible.

MECHANIZED ARMY WILL WIN NEXT WAR

President Crowell, of the Army Ordnance Association, in his address, asserted that his feeling is that this automotive development is one of the most important today and that the future army must be provided with equipment of this kind. If infantry cannot stand in front of a line of advancing tanks, it means that we must have a mechanical army and that great masses of infantry will be of little use. Battles may be fought with land battleships. Will not tanks for land use be developed along the lines of battleships? he inquired. The war of the future will be won by the army having the mechanical equipment, and this fact, he thinks, is actuating the Army today in pushing the developments described by Major Campbell.

Plating of the bore of small arms with chromium to preserve their rifling, which he stated had been discussed by the Ordnance Department during the day on which the Section meeting was held, interested him greatly, said Mr. Crowell. The plating increases the life of the 0.30-caliber rifle from 50 to 100 per cent, and he has a feeling that this plating can be extended successfully to the larger guns, with great resultant economy.

Notwithstanding the mechanizing of warfare and the increased use of airplanes, Captain Lohr, in his address, said that from time immemorial men have had to occupy the terrain to achieve victory in war. They cannot be transported in sufficient number in airplanes and in tanks, hence the need for transport trucks, munition vehicles and highways. This raises the problem of bridges to sustain the weight of the vehicles, including tanks, mounted guns and tractors. Experiments with double pontoons showed that bridges so put together would sustain a very heavy tank, and the Engineer Corps now has under development a pontoon about double the size of the old one, with correspondingly heavy stringers and floor-boards. But such boats are so heavy that they are difficult to transport on wagons. Considerable progress has been made experimentally with duralumin for pontoon construction.

In cooperation with the Ordnance Department and the Anti-Aircraft Corps at Aberdeen Proving Ground, the Engineer Corps is also doing considerable development work on searchlights and their control, said Captain Lohr in conclusion.

Army Vehicles Require Great Power

The meeting was brought to a close with an address by Alfred F. Masury, vice-president of the International Motor Co. and a member of the Ordnance Advisory Committee of the Society, who remarked that the work of the Ordnance Department, as reviewed by Major Campbell, was certainly interesting and that the policy of his company generally has been to allow the inventor of truck or tractor attachments to have one of its chassis to try to make the device practical, with the hope that he would succeed and that it could be built commercially and sold for use in the oil and lumber regions. One difficulty presented by the types of vehicle wanted for ordnance work is that the power that is necessary to haul guns and other ordnance is two or three times greater than that used in commercial trucks. Disregarding the power loss through crawler treads, the power required merely to haul the heavy loads is entirely out of the realm of commercial utility.

Mr. Masury also commented ironically upon the impassable roads encountered in a test of trucks hauling anti-aircraft guns from the League Island Navy Yard to Indian Head and to Quantico for the Marine Corps. However, the work is interesting, he said, and it is a great pleasure for the Ordnance Advisory Committee to participate in it.

CONFIDENCE CREATED IN AVIATION

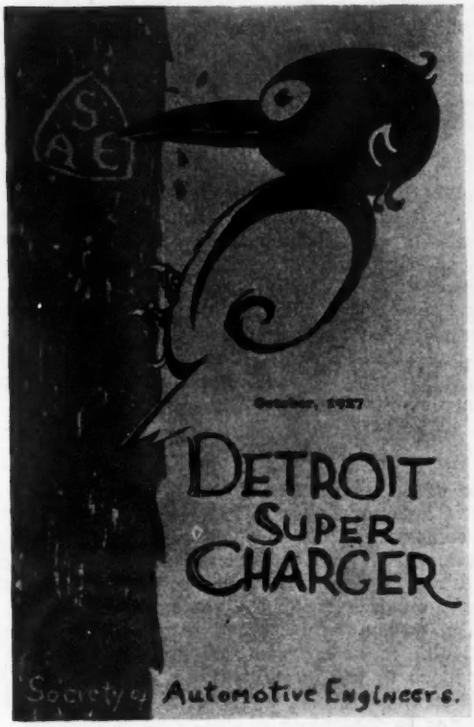
Inspirational addresses that engendered much confidence with respect to the future of commercial aviation among the 160 members and guests of the Indiana Section, were given at the regular meeting of the Section on Oct. 13, at the Severin Hotel in Indianapolis. Statements made by George T. Bryant, former business manager of the Central Airways, Inc.; William B. Stout, of the Stout Metal Airplane division of the Ford Motor Co.; William G. Wall, consulting engineer of Indianapolis and presidential nominee of the Society for 1928; and George M. Williams, president of the Marmon Motor Car Co., went a long way, in the opinion of Raymond F. Buckley, secretary of the Section, toward restoring the confidence that had been much impaired by the many disasters that occurred in the last few months in transoceanic flights.

The dinner which preceded the meeting was attended by 50 members.

NEW DETROIT SECTION MOUTHPIECE

Under the name *Detroit Super Charger*, the first number of a new publication, that is to carry to its members each month the announcements and news of the Detroit Section, made its appearance in October. It is a cousin to the Metropolitan Section *Booster*. The first number of the *Super Charger*, which has a most artistic and attractive cover printed in red and black on a brown and sepia background, announces that the Book Cadillac Hotel has been chosen for the Section meeting place; that meetings are to be held once a month this season instead of semi-monthly; that speakers and papers already arranged for as a result of much active work done by the officers through the summer assure a wonderfully profitable and interesting season; that the Membership and the Reception Committees will boom the Section membership and see that all who attend the meetings are made acquainted with one another; and that arrangements have been made for high-class entertainment at every meeting in addition to a good dinner.

Some of the speakers and subjects for coming meetings are President J. H. Hunt, with a message of general interest; Charles F. Kettering; William B. Stout, who is to address the November meeting; an inspection visit to the Morgan & Wright tire factory; four-wheel brakes; new shock-absorbers, rubber shackles, ball-bearing shackles and saddle seats; engines; and motor-truck design. A production meeting on the subject of vehicle frames is being planned for, and it is hoped that Governor Green, of Michigan; Mayor Smith, of Detroit, and other prominent men



can be induced to address some of the meetings on the subjects of automobiles, good roads and bad drivers.

The first number of the *Super Charger* carries a portrait of and greetings from Chairman Walter T. Fishleigh, of the Section.

LARGE-SCALE OPERATOR'S INFLUENCE

R. E. Plimpton Tells Chicago Section How Design and Construction Are Affected

To solve fleet-operation problems successfully, a professional consciousness is needed among the supervisors and the engineers engaged in the operating field, awakened by analyzing and making known generally the methods and practices used by the operators of individual fleets of motor-vehicles, according to Mr. Plimpton, associate editor of *Bus Transportation*, who presented his paper on the above subject at the Oct. 11 meeting of the Chicago Section, held at the headquarters of the Western Society of Engineers. F. G. Whittington was chairman.

In developing his subject, Mr. Plimpton asked the following questions and commented upon them: Has the operator any influence on design? Is that influence good or not? Whatever the influence is, can it be improved and made more effective? If it can be made more effective, how can this be done? If it cannot be made more effective, what is the reason?

Mr. Plimpton said that, regardless of variations in duties and of conditions in organization, each large-scale operator is vitally concerned with matters of design and construction. This applies not only to the complete vehicle but also to wearing parts such as tires, brake-lining, spark-plugs, fuels and lubricants, all bulking large in their effect on operating costs. He called attention to the difference between having vital concern about a subject and having influence on that subject. The first is more or less static; the second should mean a share in the progress of the art and a definite contribution

to the better adaptation of motor-vehicles to their various tasks.

First reviewing the situation insofar as it relates to the standard design as developed and produced in the factory, there are two widely divergent opinions, said Mr. Plimpton. The opinion of the operator indicates that he conducts a testing laboratory for the manufacturer and that the supervisors in the larger installations are acting as consulting engineers for the factory and its service department. Some operators even claim that they are forced to take over functions of the production end of the factory, and to complete the vehicle before it can be put to work. Carried further, this opinion indicates that the operator alone is responsible for all improvements and that the factory engineering department, with all its facilities for designing and experimentation, is greatly influenced by the suggestions of the operator. At the other extreme is the view held by the factory engineer who may deny absolutely the value of ideas or suggestions for improvement that are made by the operator unless they can be investigated at first-hand and the surrounding and perhaps controlling conditions taken into consideration. Obviously, Mr. Plimpton said, both the foregoing opinions are overdrawn.

Collection of Data

The use of a system in collecting two kinds of data is necessary if an operator is to pass reliable judgment on design and construction; that is, data with regard to cost as well as data with regard to defects. Many companies collect data in regard to defects, but these data may be tabulated under special subdivisions of the parts, such as bodies, chassis and the like, without any attempt to place the responsibility on a particular make or type of vehicle. The totals constitute a reproach of the maintenance department but they do not permit an analysis for the determination of whether the trouble is due to faulty maintenance or to incorrect design. Most truck operators content themselves with a record of time out for repairs as compared with working and with idle time. Although this labels an offending vehicle, it does not record specifically what the difficulty is. The cost-keeping methods may be satisfactory in general, but they are not designed for study of pecularities of equipment. Once installed, they become largely a matter of routine, and the ordinary system seems to make it impossible for any actual records to be kept if they are out of the ordinary. One of the important tasks of the equipment engineer is to handle such records at the same time he is observing the performance of the equipment under operating test.

Auxiliary Service and Safe Operation

In the discussion following the paper, O. W. Young, of the Hyatt Roller Bearing Co., asked whether the electric-railway companies that operate motorcoach equipment as auxiliary to their regular service had made such service pay, or whether these companies operate auxiliary motor-vehicle service to forestall competition in such service. Mr. Plimpton replied that many of the electric-railway companies operate their motorcoach service at a loss. However, where such service is inaugurated, it is on routes that otherwise would have been covered by trolley service at much greater expense, so that the net income really is increased by the motorcoach operation.

Disregard of the safety of passengers observed by Walter Martins, of the Fashion Automobile Station, Chicago, during a recent trip from Milwaukee to Chicago, was deplored by him. He mentioned seeing vehicles of two rival motorcoach companies, the drivers of which had exhibited great recklessness. He asked whether any definite regulations are in effect that control the way in which motorcoaches shall be operated on the highways so that passengers will not be jeopardized. Mr. Plimpton replied that each State and each county has definite police powers and that safe operation can be compelled.

[1] See The Journal, June, 1927, p. 722.

Accounting and Parts Replacement

In reply to the question whether it is possible for the superintendent of a fleet to have charge of the accounting, Mr. Plimpton said that the more interest the superintendent takes in accounting the more valuable he is to the employer. Although it is not possible to take care of all the accounting in the superintendent's department, many of the figures could be assembled in that department and would be of considerable value.

Other subjects brought up for discussion included differences in respect to methods of replacement of parts, and analyses of what constitutes the best practice in several different lines.

BUFFALO SECTION MEETINGS

Members Visit Airport in September and Discuss Valve-Spring Surge in October

Instead of holding an indoor technical meeting, about 150 members of the Buffalo Section visited the Buffalo Airport on Saturday, Sept. 24, and 48 were given rides in a Ryan airplane.

Upon arriving at the airport at 1:30 p. m., the members of the Section and of affiliated sections of other societies, together with their wives and invited guests, inspected the Stout tri-motored airplane that makes daily trips between Detroit and Buffalo, and which left the airport for Detroit at 2:00 p. m. The visitors then assembled on the roof of the administration building, where Nathaniel Duffy described in an interesting address the chief features of the new municipal airport, such as the buildings, the lighting system and the airplanes. Following this, the speaker conducted the visitors on an inspection trip through the various structures.

Three parachute jumps at heights of 300 to 500 ft. were made to show the operation of the Irwin parachute at close range, after which it was inspected and its details of construction and operation explained.

Material and Heat-Treatment of Springs

The regular October meeting was held on the 4th of the month when W. T. Donkin, of the Cleveland Wire Spring Co., presented a paper on valve-spring surge.[1] Chairman William R. Gordon presided. When Mr. Donkin had finished the presentation, an extended discussion followed, in which the material, method of treatment, engine-speed, spring endurance, and the question of springs in airplane engines were debated.

Commenting on different designs of spring shown by Mr. Donkin, Chairman Gordon said that one obvious difference between the two types of spring was that in the new type the pitch diameter, wire size and number of coils had been decreased and that therefore the stress of the spring had obviously been increased, as the spring had less metal to carry the imposed load. He asked what material and heat-treatment were being used and what the elastic limit of the spring might be and also inquired if it might not be possible to avoid periodic vibration by using a double spring, one to dampen the other. To these questions Mr. Donkin replied that, although the maximum stress had been increased as indicated by formulas, in reality the stress was decreased in the redesigned spring, as was proved by running the new springs in an engine. Springs of the original design broke after they had run about 1½ hr. at 1490 r.p.m., whereas the redesigned springs did not give any trouble. Motion pictures of the spring surge showed that at one instant certain coils at one end were compressed solidly together, resulting in a stress of 69,000 lb. per sq. in., while at the other end the coils were spread apart. The next instant the conditions were reversed. Measurements of the pictures showed that the opening gave a stress range of 65,000 lb. per sq. in.

As a result of tests made at the plant of his company, he said that the company recommends the use of electric-furnace chrome-vanadium steel in valve springs and that, to obtain the best results, this must be heat-treated after the spring is

MEMBERS OF BUFFALO SECTION VISITING AIRPORT AND INSPECTING RYAN AIRPLANE IN WHICH 48 WERE GIVEN FLIGHTS

wound from annealed stock rather than before winding. When springs are made from material that the spring maker calls "all tempered wire," stresses are placed in the material in winding which subsequent heat-treating does not remove and fractures start from the inside of the spring. He said that the company had tried linking springs by putting a retainer in the center and, although good results were not obtained, he thinks that the idea can be worked out successfully.

WIRE SURFACE-DEFECTS REMOVED WITH ACID

E. W. Kimball, of the Vacuum Oil Co., inquired whether some spring breakage is not due to dirty or defective dies used in drawing the wire. The problem of the fatigue life of coiled-wire springs and its relation to defects in material had been gone into extensively, said Mr. Donkin, and there is no question that surface defects which were supposed to be negligible become a big factor when the spring is running under very highly stressed conditions. At the present time the company he represents is having wire made to its own specifications and examines every coil of wire before it is made into valve springs. The wire is placed in hydrochloric acid, which removes about 0.002 in. of material and reveals defects. The wire is then dried and examined under a microscope that magnifies 10 diameters. This etching method has revealed surprising surface defects, such as seams, checks, slivers, and transverse marks or electro-structure. Although wire has been obtained from Germany, Sweden and England and has been tested, the American practice in wire drawing is, he said, better than the foreign practice.

Commenting on a statement made by Mr. Donkin that, with the new spring design, the pressure under the valves was approximately the same when the valve was closed as when it was opened, William E. John, of the Buffalo Gasoline Motor Co., asked what effect this has in holding the push-rod roller on the cam. The load on the cam is ample to hold the follower down, replied Mr. Donkin, who explained that when the spring coils surge the coils are compressed at one end and when the pressure should be downward it really is upward. In the redesigned spring the pressure is increased only about 4 lb. but, due to absence of surge, there is no trouble from floating valves. When the push rod is lifted the load on the spring is increased, but surge is not a condition entirely of loads; a spring may be amply loaded but if poorly designed it will surge.

The results obtained with double springs, said Mr. Donkin in response to another question by the same member, have shown that the double springs work absolutely independently of each other. Although they have different surge periods that may counteract each other, they may also coincide. Answering a question by another member, he stated that the original spring vibrated 10,750 times per min. and that this number had been increased to 17,600 in the redesigned spring. Asked by Chairman Gordon at what maximum speed a valve will follow the cam, Mr. Donkin stated that the springs have performed up to 7800 r.p.m. on racing engines.

SMALL-DIAMETER STRAIGHT SPRING PREFERRED

Gustaf Carvelli, of the Curtiss Aeroplane & Motor Co., asked for the opinion of the speaker regarding straight springs as compared with cone-shaped and helical springs, and raised the point that chrome-vanadium steel seems harder to control in heat-treating than does carbon steel. He stated that he knew of chromium-vanadium-steel springs stressed to 42,000 lb. that would not last 50 hr. The tensile strength of the wires in these was from 300,000 to 375,000 lb. per sq. in. After having gone thoroughly into the question of straight, conical, and barrel-shaped springs, his company found, said Mr. Donkin, that a small-diameter spring is always to be preferred. With springs having large coils, the up-and-down-pitch diameters are large, and surge always develops with a larger diameter.

Commenting on the possibility of the use of piano wire, Mr. Donkin stated that this usually is a high-carbon wire made from Swedish rods and in the drawing operation is subjected to a pressure of 300,000 lb. per sq. in., so the metal is worked almost to its ultimate limit. Another objection is the longitudinal flow of the metal, resulting in longitudinal defects. Both the best and the worst results have been obtained with music wire.

The old method of heat-treating springs was to place them on pans in a box-tight furnace and, after heating, to remove them with a rod and take them to an oil-quench stand. When the rod was inserted it would chill certain sections, and contact with the pans would also result in cold material for quenching. In the electric furnace designed especially for the purpose, the springs are placed on trays, given a slight pre-heat and then another heat. The pan is then tilted at an angle of about 45 deg. and passes down a chute against two bars, where the springs are spilled into an oil quench without having passed into the cool air. Next they go through a washing machine and then through a drawing furnace where they are drawn for approximately 35 min. at a temperature of about 700 deg. fahr.

The speaker agreed with a member who commented that most defects seem to come from hair lines. Whole coils of wire have been cut up in search for hair lines and it has been found that 90 per cent of the defects can be discovered

by etching. Wire that was die scratched gave very poor results and this was always thought to be a very serious defect, but, on test, wire from which the hair lines were removed by etching gave an average result of about 10 hr. of running in the engine, as compared with 30 hr. of life test at 3000 r.p.m. which is required of the regular output of valve springs.

Design and Material Decide Spring Life

With transoceanic airplane flights of from 30 to 35 hr. in mind, A. F. Carlson inquired if the United States Government or any aircraft-engine manufacturer requires special tests on valve springs. To this Mr. Donkin observed that he believes that aircraft engines do not operate at such high speed as automobile engines, the speed of the Wright Whirlwind engine being about 1800 r.p.m. On this subject Mr. Carvelli stated that when the endurance record of 51 hr. was broken with the Wright engine the engine ran at about 1300 r.p.m. but most of the engines now run at about 2000 r.p.m. He observed that he did not think there is an automobile engine in which the valve springs would stand up for 50 hr. at 40 m.p.h. Mr. Donkin stated, however, that he had run an engine continuously for 500 hr. at 3000 r.p.m. and that it was simply a matter of getting the proper spring design and material. Continuous operation at maximum speed is much easier on the valve springs than operation at variable speed. Asked by Mr. John if the spring maker can be expected to make springs that will stand up for 750 hr. at 1000 to 14,000 r.p.m., Mr. Donkin replied in the affirmative.

Charles Pleuthner, of the Pierce Arrow Motor Car Co., asked what Mr. Donkin's experience had been with high and low stress with the roller type and the mushroom type valve-lifter, and stated that he had found it necessary to use a roller-type lifter with springs of high load. Mr. Donkin said that his tests have been made with a mushroom-type lifter. Ikarus Mandolf explained that the roller-type lifter provides greater bearing areas and with adequate lubrication will give long service, whereas with the mushroom type the cam used must have a sharp point which affords only a line contact on the flat face of the lifter and the lubricant is forced from between the surfaces so that wear results.

Is there any secret about the steel analysis? asked M. M. Bassett. To this Mr. Donkin replied that his company uses S.A.E. steel No. 6150, that the time in the furnace varies from about 12 min. on 0.120-in. diameter spring to 18 or 20 min. on 3/16-in. material and, because of the greater mass of the latter, the drawing time is about 40 min. compared with 20 min. for the former.

Rust Causes Many Spring Breakages

Commenting on a remark by Mr. Carvelli that valve springs in aircraft engines break occasionally, Mr. Donkin mentioned that the spring might rust and be stressed concentrically at that point so that it would soon fail. The springs could readily be plated to resist corrosion and a great deal of spring breakage could thereby be avoided. Investigations he had made on springs that had been returned because they were pitted on one end showed that water had collected on the springs and that the pitting was due to rust. However, when the springs were tested on an engine they could not be broken.

Sets of seven or nine valve springs are used on each valve of an aircraft engine, said Mr. Carvelli, so that if one breaks a number of springs would be left. In most cases of breakage, one or one and a half coils of the springs break away. Mr. John remarked that if one spring breaks all of the springs of the set might as well go too, as the pressure on the valve is relieved. Some of the valve-spring failures are often due to breakage at the top of the valve or to improper heat-treating of the valve, which results in breakage and the valve dropping into the cylinder. He asked Mr. Donkin which he regarded as more important where space for the valve spring is limited, spring length or diameter. To this Mr. Donkin replied that the solid length that can be given a spring design is more important than the diameter, as the diameter can be varied but the length cannot be. Few designing engineers give sufficient consideration to this factor; the valve spring is the last thing of which they think, and the spring maker must do the best he can under the circumstances.

VALVE-SPRING SURGE SHOWN

Cleveland Section Members See Motion Pictures and Discuss Spring Design

Motion pictures of valve springs in action were a feature of a well-received paper on valve-spring design presented by W. T. Donkin, of the Cleveland Wire Spring Co., at the first fall meeting of the Cleveland Section, held Oct. 17 in Carnegie Hall. In the words of Secretary Ferdinand Jehle, it was a great meeting and the motion pictures were highly interesting and instructive. They were taken for the purpose of studying the surging action of valve springs in a running engine, the results of which study were presented by Mr. Donkin and H. H. Clark at the Summer Meeting and published in the June issue of THE JOURNAL, p. 722. The technical session, which was preceded by a dinner at 6:30 p.m., was presided over by Mr. Jehle, to whom L. S. Bradley, chairman of the Section, relinquished the chair.

So many other problems held the attention of the engineer in the early years of automobile manufacture that he did not have much time to think of valve springs, said Mr. Donkin, but now these are being studied. Due to the steady increase in engine operating speed, correct operation of the engine now depends on correctly designed valve springs. After tracing spring design back to Hooke, who expounded a law of elastic bodies in 1676, and giving a formula for calculating the loads in pounds per inch of deflection required to satisfy the valve in closed and open conditions, the speaker stated that experience has set the maximum stress in the neighborhood of 60,000 lb. per in. and the maximum stress-range at about 25,000 lb. per in. Tests have shown that stress range is more important than the maximum stress up to the point of elastic limit, as with a high stress range the material is put through a large angle of twist that tends to fatigue the material quickly and to cause early failure of the spring. High maximum stress with a low stress range is therefore less destructive.

Alloy Wire Heat-Treated After Coiling

Material and heat-treatment must also be considered in valve-spring design; expected results were not obtained when alloy-steel wire was heat-treated by the continuous process used previously for oil-tempered wire, according to Mr. Donkin. Tests covering a period of 5 years showed that springs made from soft wire and heat-treated after coiling are much superior to springs coiled from heat-treated wire. Taking average results from oil-tempered-wire springs heat-treated before winding as unity, springs made from electric-furnace chromium-vanadium spring-steel heat-treated before winding give a result of 0.9; springs made from carbon spring-steel heat-treated after winding give a result of 5, and springs made from electric-furnace spring-steel heat-treated after winding give a result of 10. When price is a major consideration, said the speaker, his company believes that results secured from a carbon spring-steel heat-treated after coiling more than offset the slight increase in cost due to the method of treatment.

Regardless of extreme care in selection of material, in design and in heat-treating, failure sometimes occurs after comparatively short service. This has been traced, said Mr. Donkin, to resonance between the natural frequency of the spring and the frequency of the forced vibration as related to the camshaft, resulting in valve-spring surge. The speaker then showed motion pictures of this surging action and gave an analysis of it similar to that in the paper presented at the Summer Meeting. In conclusion, he stated that valve-spring design calls for (*a*) static design consistent with the valve loads called for and with conservative stresses and stress range, (*b*) good sound material properly heat-treated, and (*c*) dynamic design for the best engine-operation.

How Spring Surge Is Made Manifest

Any idea that surging of the valve spring is insidious and unnoticeable was deprecated, in opening the discussion, by Chairman Jehle, who said that it "sounds like a kid running along a picket fence with a stick," and by M. R. Wells, research engineer, who said, "we used to call it St. Vitus dance." A good way to detect seamy spring stock, suggested to Mr. Wells during the war by a spring company, is to heat it to a good red and quench it in oil, which tends to open the seams wider but does not start seams not already present.

A hard alloy spring that has seams in it will fly to pieces when stepped upon, and the fractures will follow the cracked surface. A factor not mentioned by Mr. Donkin, said Mr. Wells, is the twisting at the lower ends of the spring when running in an engine. This is most noticeable on the push-rod, which twists back and forth as the spring is compressed and released. Advantage can be taken of this to rotate the valves. There is some evidence that this action has considerable to do with spring breakage.

Mr. Donkin stated that he, too, had noticed that when the spring is vibrated at its critical period the spring and valve rotate rapidly and believes this should interest the valve maker. In response to a query by Mr. Wells regarding his experiments with springs of variable pitch, Mr. Donkin stated that this idea of having a larger pitch or opening between coils in the middle of the spring has not proved satisfactory, although in some cases it has helped in solving the problem.

Double, Multiple and Tandem Springs

Chairman Jehle regretted that motion pictures had not been taken of spring action with the engine run at about 1500 r.p.m. and then shut off to show the stage at which the forced vibration and the free vibration of the spring synchronize. If this stage is not too long, the driver might drive through it. If the spring-vibration period is only 50 r.p.m. below the point of intersection of the horsepower curve and the curve for power required for maximum car speed, the engine power will be reduced so that the operator cannot drive through the period, but if the vibration point is at one-half the maximum speed-range, it may be possible to drive through the period.

E. W. Weaver, of the George T. Trundle Engineering Co., observed that he had remedied the trouble by using two springs, one inside of the other; but Mr. Donkin and Mr. Wells reported that, although such springs have different periods, they may surge violently at the same time at some engine speeds. Multiple springs were suggested by P. F. Hackethal, of the Duroseal Corporation, and Mr. Wells stated that if the spirals of multiple springs are in opposite directions the twisting difficulty will be overcome. The twisting or rotating action, if violent, is bad for the valve seat, according to Robert Jardine, of the Rich Tool Co., who said that a hard part in the valve will scour the valve seat; but a slow rotating motion is beneficial rather than otherwise, as it aids in the uniform cooling of the valve. Commenting on a remark by Mr. Donkin that trouble from breaking springs in a motorcoach had been overcome the week before by the use of redesigned valve springs, Mr. Jardine said that if the spring surge is anywhere near the usual speed range of the motorcoach the valves become too hot, as the period of rest of the valves on their seats is too short for the heat to be dissipated through the valve seat and the valve stem.

With springs in tandem, as suggested by Chairman Jehle, excellent results were obtained up to about 53 m.p.h., said Mr. Donkin, but at higher speeds the springs made a great deal of noise. So far, the idea has not proved successful.

SHORT-HAUL DELIVERY VEHICLES

Lee W. Oldfield, of the Pak-Age Car Corporation, of Chicago, was the speaker of the evening at the Dayton Section meeting on Oct. 25. His subject was Special Vehicles for Short-Haul Delivery Purposes. The session was preceded by a members' dinner at 6:30 p.m.

Safety in the Air

THE modern airplane is light, but of excellent structure, and it is very rarely that we hear of a structural failure in the air. The air-cooled aviation engine is now a highly reliable mechanism. Careful installation of the powerplant has eliminated fire hazard to a large extent. But, while the airplane has made marvelous progress in speed, economy and load carrying since its early days, it is still lacking in safety from an aerodynamic point of view. Improvement in aerodynamic safety characteristics has, in fact, been sadly neglected by designers who have bent their energies largely to progress in performance.

When engine failure does occur in cross-country flying, safety depends on the availability of an emergency field. The emergency field may be broken up in surface and very small. The average airplane lands too fast and rolls too far in such terrain. Moreover, the field may be, not only small, but surrounded with obstacles such as trees and wires. The only possible approach is then on a steep glide. But a steep glide on the airplane of today on landing frequently means disaster.

In getting out of the small field the converse of the above circumstances is found. The take-off run is too long, and the plane while climbing rapidly may not climb steeply enough to clear surrounding obstacles. A frequent source of accident is when a plane is climbing rapidly and the engine suddenly fails. The plane may "stall," and the pilot lose control and go into the dreaded "spin."

In fog flying, the pilot no longer has the horizon to guide him. He is completely blind, and gusts of wind and disturbances may make his instruments no longer reliable. He may then be flying in the most extraordinary and dangerous attitudes without being aware of it, unless the plane is such that it is always stable and will keep an even keel independent of the pilot's efforts.—Guggenheim Foundation.

Aberdeen Proving Ground Demonstrations

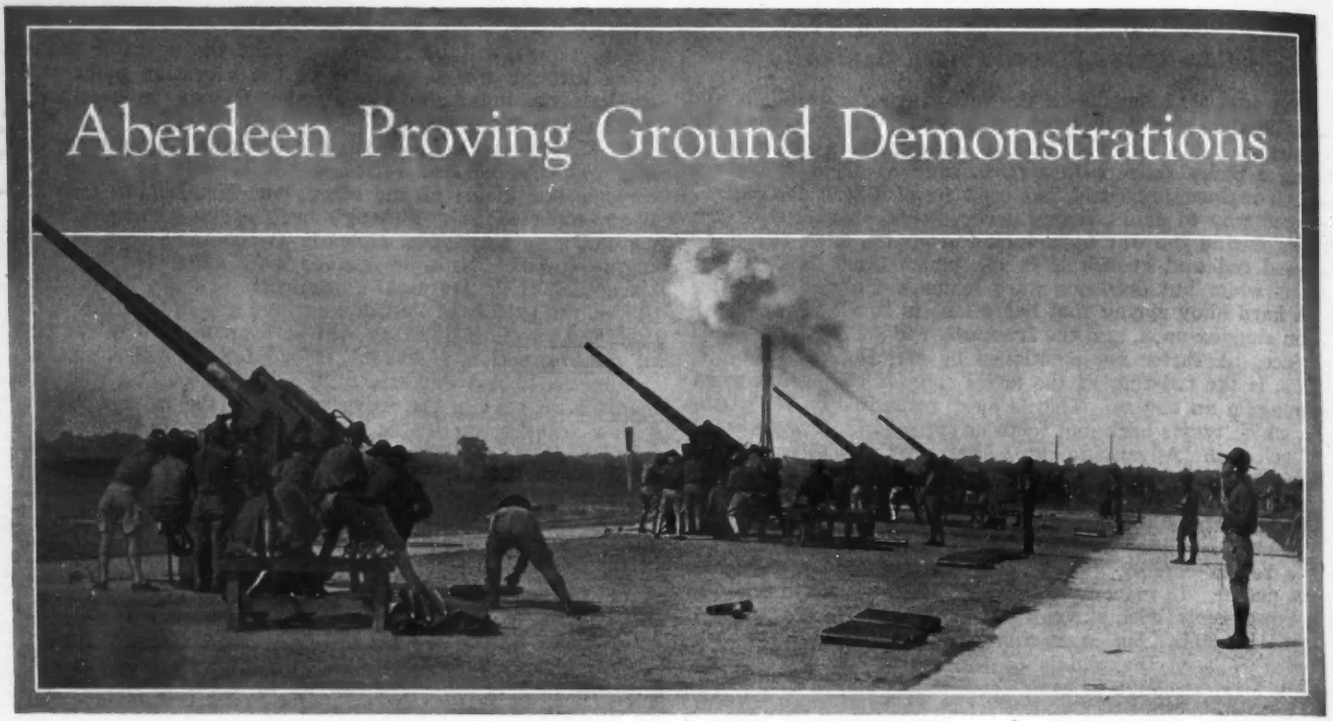


Photo by Underwood & Underwood

ALL that they were cracked up to be, and more, may truly be said of the ordnance demonstrations at Aberdeen Proving Ground, Maryland, on Oct. 6. Every event went off with a bang; in fact, it was a bang-up time for the visitor spectators, whose number has variously been estimated at 5000 to 10,000. How many of these visitors were members of the Society is not known, but the Army Ordnance Association, which put on these remarkable demonstrations as its Ninth Annual Meeting, extended invitations to the members of the Society, the Military Order of the World War, the American Society for Testing Materials, and the Quartermaster Association to participate in the event. Certainly a large percentage of the attendants were from the Pennsylvania, Washington and Metropolitan Sections, as special Pullman trains, some of them comprised of a dozen heavy coaches, brought full loads from New York City, Pittsburgh, Philadelphia, Baltimore, and the City of Washington. Many hundreds of private automobiles, in addition, poured into the Proving Ground from early morning until nearly noon, bringing their quotas of Army reserve officers and civilians. Without doubt, the number of such cars aggregated 1000, most of them bearing Maryland, Pennsylvania, District of Columbia and Delaware license-plates.

The Army Ordnance Association anticipated the sale of 1500 tickets for meals, but before breakfast was served to the early arrivals, the number of tickets sold had reached 3900. Seating arrangements had been made for 1000 diners, and kitchen and serving arrangements that had been made for the anticipated number of visitors were utterly swamped. Arrangements for all the rest of the program, however, were excellently planned and executed.

Rounds from the Great Guns

Visitors were transported from the Service Club in first and second sections of the Aberdeen Proving Ground train to the locale of the various events, the first of which was the firing, about 10:00 a.m., of the 16-in. coast-defense gun mounted on a barbette carriage. This is the largest weapon constructed for seacoast defense in the Country and has a maximum range of more than 30 miles with a projectile weighing 2340 lb. propelled by a charge of 860 lb. of powder. Just before the firing of this and other large guns, the spectators gathered nearby were advised to stop their ears with their fingers as a precaution against the breaking of ear-drums. It was observed afterward that several of the windows in the Proving Ground train halted nearby had been shattered by the concussion.

Next came the firing of one round from an 8-in. gun and one round from a 12-in. gun, each mounted on a railroad carriage. The former has a range of 34,000 yd. with a 200-lb. projectile. The latter which has a range of 27,900 yd. with a 700-lb. projectile, can fire at angles up to 38-deg. elevation. The carriage of the 8-in. gun permits firing in any direction through 360 deg. of circle.

Anti-Aircraft Batteries Now Formidable

Of more immediate interest to the members of the Society were the day and night demonstrations of anti-aircraft firing by the 61st Coast Artillery Regiment from Fortress Monroe, Va. These were spectacular in high degree, particularly the night firing at cloth targets towed by airplanes. The stream of 0.30 and 0.50-caliber tracer projectiles from the Browning guns mounted both singly and in multiple, and the tracer projectiles from the 3-in. and 105-mm. guns, clearly revealed the peril in which an airplane would be if under fire. The 3-in. projectile weighs 15 lb. and attains a vertical range of 10,000 yd. The rate of fire is about 28 shots per gun per min. The 105-mm. projectile weighs 33 lb., has a vertical range of 12,000 yd., and the rate of fire is about 15 shots per gun per min. The guns fire either shell or shrapnel and the latter could be seen to burst all around the targets, which were at times at a distance of 2½ miles and barely visible to the best unaided eye by daylight, and also when illuminated at night by seven searchlights, one of which was of 700,000 cp.

The targets are only 5 ft. in diameter and 27 ft. in length and were towed at a maximum distance of 2500 ft. behind the airplane. Three of the targets fired at in the forenoon at ranges of 1 and 2½ miles were displayed on the lawn in front of the Service Club at the lunch hour. One showed 57 shrapnel holes as a result of 77 rounds fired at it, and another showed 14 shrapnel holes as a result of 56 rounds and also one large hole where a shrapnel case had passed through it.

The climax of the day's demonstrations came just at the finish of the program when the last round of shells from the 3-in. anti-aircraft guns cut the towing cable of a target at a range of 2½ miles and the target floated earthward, whereat the assemblage broke into spontaneous applause.

The remarkable fact about the development of this air-

craft-defense ordnance is that the range-finder is connected electrically with the batteries of anti-aircraft guns and automatically aims and fires them at the objective, so that all the gun crews do is to load the guns and catch the empty ejected shells. The altitude of the airplane is found by a stereoscopic height-finder, and two manually operated telescopes transmit all data to the guns, making all ballistic corrections and giving the necessary information to the fuse-setter for timing the shrapnel. At night the approach of an airplane is detected by a sound horn, which locates the airplane at a distance of 10 miles with an error of only ½ deg. Searchlights then quickly pick the airplane up so that the range-finder can ascertain its height.

Airplanes Drop Demolition and Smoke Bombs

Following the daylight anti-aircraft demonstration, an all-too-short inspection of aircraft at the flying-field was made before the train took the visitors to the main front. The only events at the flying-field were two parachute jumps from airplanes and a demonstration of radio communication with an airplane. At the main front, airplane attacks against an imaginary enemy consisted in dropping from a Martin bomber eight 100-lb. and one 600-lb. demolition bombs equipped with instantaneous fuses. The dropping of these bombs, which are for use in attacking ammunition and supply dumps, storehouses, munition factories, railroad terminals and bridges, and the like, was preceded by a yellow smoke-signal. A demonstration was also made of an airplane attack with rapid-fire guns against ground troops. Smoke-screen bombs also were dropped and a smoke curtain, which is a development of the Chemical Warfare Service and the Air Corps, was laid down by an airplane. Another airplane made a simulated mustard-gas attack.

Tanks and Mobile Gun in Mimic Battle

Immediately after dinner, the guests were taken by train again to the main front to observe mimic warfare with tanks, horse-drawn artillery and infantry brought up in motor-trucks. There was a preliminary parade of tractors, of which close inspection was invited later.

Then the tanks, some mounting machine guns and others 37 and 75-mm. guns, and a large 155-mm. gun mounted on a motor carriage, advanced in line across the field firing explosive shells at the enemy assumed to be concealed in the brush and woods about 1 mile distant. In the rear of these the infantry advanced, firing rifles as the tanks deployed to right and left. When the infantry had cleared the immediate

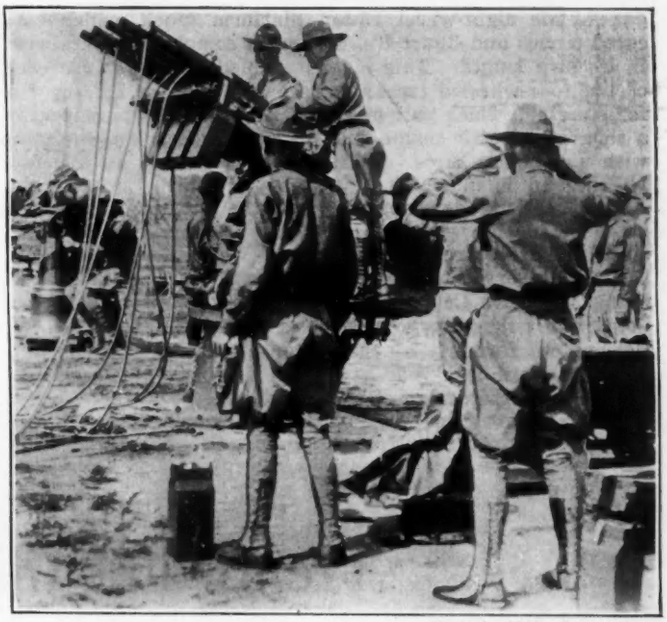


Photo by Wide World Photos

Anti-Aircraft Multiple Machine-Gun Firing 2000 0.50-Caliber Shots per Minute

foreground, the artillery batteries were brought into action. Next came the firing of chemical and smoke bombs from stationary mortars and the laying of a smoke screen with candles.

Nearly all of the equipment demonstrated represented post-war developments and is the latest American Army ordnance.

Announcement of each event, with a description of each piece or pieces of artillery to be used was made to the assemblage by an announcer speaking into a microphone connected with a group of loud-speaker horns mounted on the top of a motor-van.

Eight-Wheel Gas-Electric Truck a Feature

From the battlefront the visitors went to the concourse beside the quartermaster's office where motor-trucks and tractors were lined up for exhibition. A great deal of curiosity and interest was here shown in the new Versare

Photo by Wide World Photos

Double-Turret Divisional Tractor-Tank Advancing in Line and Firing at the Enemy

gas-electric eight-wheel 15-ton platform truck, which executed circles and figure 8's, turning a complete circle almost in its own length. This it was enabled to do because each of the four-wheeled trucks is used not only for driving but for steering. Each pair of wheels of each truck is driven by a separate electric motor, and all eight wheels are equipped with pneumatic tires. This truck was built in Albany, N. Y., and is under test at Camp Holabird, Md., by the Army. It is a development from the Versare Company's six-wheel design which is used for motorcoaches and has six-wheel drive from three motors.

Another very interesting development was the six-wheel-four-wheel-drive Coleman transport trucks built in Littleton, Colo., and now undergoing test at Camp Holabird. A. W. Herrington, formerly of the Motor Transport Division and stationed until last year at Camp Holabird, is largely responsible for the design of these trucks.

A motor fire-engine designed by the Quartermaster Corps and provided with a 400-gal. pump was also displayed. This last was redesigned from parts of Class-B trucks and is for the replacement of commercial motor fire-engines at Army camps.

Next came a business meeting of the Army Ordnance Association in the Administration Building, at which addresses were made by prominent guests, and an inspection of World-War artillery and automotive materiel of the Allies and Central Powers which is housed permanently in the Exhibition Building.

Last on the program was the demonstration of anti-aircraft night-firing, already described.

The special trains pulled out for New York City, Pittsburgh and the City of Washington between 7:30 and 8:00 p.m., carrying home their heavy loads of weary but tremendously interested visitors. The purpose of the meeting and ordnance demonstrations, which was to better acquaint civilians with Army requirements in the event of future hostilities and to interest engineers and manufacturers in preparedness for National defense, was well accomplished.

Trends in Military Airplanes

(*Concluded from p. 452*)

than it will be to attack it by air from a moving base on the water. It might be said that naval aviation is moving ashore to some extent to prevent the air forces of the land from taking control of the sea-coast.

In some countries, where aviation is organized as a separate unit of the national defense, this change has reopened the whole conflict between army and navy forces and there seems to be a tendency, which might well become accentuated if naval operations from land bases increase, toward the strengthening of naval aviation and the weakening of the land forces. The whole argument seems to base itself on the general proposition that people operating over the sea, from carriers, from battleships or from land bases, ought to be familiar with the sea and its peculiar problems of navigation. How much truth there is in the argument is a matter for warm debate in several important countries.

One should not, perhaps, pass even from a brief discussion of this question without noting, in naval aeronautics, the trend back toward big seaplanes for long-range patrol work. This is very striking in England and in Italy, although, as usual, the commercial operations of Germany supplied the first impetus in that particular direction.

A large variety of what one might call special planes comes to light all the time. An exceedingly light bomber with a 600-hp. special water-cooled engine, with wing radiators, and looking and acting generally more like a racer than anything else, is developed to carry a 500-lb. bomb in a diving attack on carriers. What might be called an "alert" type with a single gun, extraordinary climbing ability and high speed at great altitudes, is being built presumably to keep the sky clear of photographers and other impedimenta of that class. It looks entirely incapable of taking care of itself against a fighting machine, except by its great ability to run away from a real fight. Half a dozen other interesting developments of this sort seem to have been added to the list in the last year. In fact, there seems to be no end to the creation of new types of military and naval airplanes. These are the outward and visible signs that indicate that the trend is definitely toward engineering firms rather than toward great production facilities. In England, particularly, there is a high premium on engineering ability in the military end of aeronautics.

On the whole, one might say that there is a very distinct trend in military and naval aeronautics toward diversity of types and uses, toward speed in the pursuit classes, and toward higher flying-performance in the heavy types of bombers. Everywhere there seems to be a trend toward higher performance, no matter what the price. In other words, in nearly all the great countries a smaller number of the best-performing ships is preferred to a larger number of mediocre equipment.

Wide Range of Subjects Covered at Transportation Meeting

News reports of the Fifth Annual National Automotive Transportation Meeting of the Society that follow show that this meeting, the first held in the Middle West, was a valuable contribution to knowledge on the subjects of operation and maintenance of automotive equipment for large-scale transportation. Of more than a score of papers and reports presented, a number dealt with commercial operation of motor-trucks, trailers and the use of unit containers; others with motorcoach design and operation; several with common-carrier legislation; three with maintenance as handled in the Army and in civilian organizations; three with rail-cars, one with shop equipment, and one with air-transport operation. The technical program is printed in this report of the meeting. Great credit for the very interesting 3-day program is deserved by the Transpotation Meeting Committee, under the chairmanship of F. J. Scarr.

Special credit for the success of the sessions and the Transportation Banquet is due to the session Chairmen, H. C. Crowell, F. C. Horner, R. E. Plimpton, and J. F. Winchester; and to Toastmaster T. C. Powell. Other members of the Committee who contributed largely by useful advice were H. L. Debbink, F. I. Hardy, F. G. Whittington, and Edward Wotton.

One of the most interesting features of the meeting was the breakfast and luncheon conferences of the Committee members, the chairmen and the speakers held before the several sessions. These made it possible for those responsible for the success of the meeting to meet one another informally.

Through the courtesy of Martin E. Goldman and a number of Chicago automotive equipment jobbers, an interesting exhibition and demonstration of the latest repair-shop equipment and tools and a number of motor-vehicle accessories was made during the 3 days of the meeting. Opportunity was also also given the members of the Society to inspect the new Diesel-engine rail-car built for the Canadian National Railways.

Members attending the meeting had the opportunity to visit the Arthur Dixon Transfer Co., the Underwriters' Laboratories, the Chicago Motor Coach Co., and the Yellow Truck and Coach Mfg. Co. It was also possible, through the courtesy of the General Electric Co. and the Electric Storage Battery Co., for them to inspect the largest storage-battery locomotive in the world.

Names and company affiliations of those who attended the meeting are listed in a subsequent page.

F. J. SCARR
Chairman of the Transportation Meeting Committee

MAINTENANCE, CIVIL AND MILITARY

Opening Session of Transportation Meeting Considers Vehicle Reconditioning

In opening the 3-day Automotive Transportation Meeting of the Society in the Hotel Sherman, Chicago, on the forenoon of Oct. 25, J. F. Winchester, chairman of the session, welcomed the 107 attendants and expressed his conviction that the Transportation Meetings of the Society will become, not only national in scope, but international, with a group of Society members going to England this month to attend the World Motor-Transport Congress and the Commercial Motor-Transport Exhibition.

The system of maintenance of motor-vehicles in the Army, whereby a large quantity of work of high quality is obtained economically from unskilled enlisted men, was described by Lieut. W. C. Thee, of the Quartermaster Corps. This system, he said, is applicable to maintenance of fleets of civilian vehicles in commercial operation. The paper is printed in full elsewhere in this issue of THE JOURNAL.

Eastern members were much interested in the paper on Maintenance on the West Coast, as presented by Edwin C. Wood, superintendent of transportation and general shops for the Pacific Gas & Electric Co., and Vice-Chairman of the Operation and Maintenance Committee.

A feature of the meeting in connection with the third paper on the program, Shop Equipment and Tools, by Martin E. Goldman, of the Automotive Equipment Association, was a very interesting exhibition and demonstrations of modern automotive shop-equipment and various accessories of importance in facilitating the quick return of disabled vehicles to service. Exhibits made by various manufacturers included equipment used in the following maintenance processes: Valve grinding and replacement, painting, battery repairs, machining, brake-lining replacement, jacks and other lifting devices, welding, drilling and reaming, vulcanizing and changing tires, wheel aligning, cylinder grinding, and washing.

The following devices also were displayed: Spark-plugs, windshield wipers, fire extinguishers, truck chains, and air-pressure gages.

Each of the exhibits, which were set up in a room of the hotel adjoining the Louis XVI room in which the meeting session was held, was competently attended by a representative of the exhibiting company who described its merits for the benefit of members.

Ways in which big fleet operators on the Pacific Coast are reducing operating costs were listed by Mr. Wood as (*a*) selection of the right type and make of automotive equipment best suited for the service required, (*b*) organization to give service and proper maintenance, (*c*) selection and control of drivers and superintendents, (*d*) the keeping of records and the mechanical history of parts replaced and labor expended, (*e*) keeping a record of each vehicle to ascertain accurately the operating cost per mile, (*f*) maintaining a cost-accounting system, and (*g*) the use of labor-saving devices.

The inefficiency of an organization, whether it is revealed in poor routing or driving, overloading, speeding, or lack of inspection, has a tendency not to give a fair estimate of the motor-vehicle's performance capability. The fleet operator, according to the author, should direct attention to the human equation when discussing costs as this factor is

making costs too high. Items due to inefficiency are not separated in cost analysis and, therefore, lead to wrong conclusions. Another point that is receiving considerable thought is the number of mechanics required to service a fleet. The staff list was mentioned as another important item of overhead. The problem of the amount of work that each man should do is one that cannot be reduced mathematically owing to the variation in requirements. It is found by operators that it is more economical to have such work as upholstering and painting done outside of their own organizations, as the volume of such work is too small to make it economical to maintain necessary trained personnel.

Labor Turnover a Real Problem

One of the chief causes for the present heavy turnover in automobile mechanics is that the mechanics are growing tired of shop work and are preparing themselves to enter professional occupations through the study of accounting, law, business, salesmanship, and the like. One of the problems of the shop superintendent is how to combat this situation. While a higher rate of pay than the existing scale will often reduce the high cost of losing a trained mechanic, this plan does not seem to have worked out satisfactorily in the endeavor to bring about reduction in maintenance costs. No other subject is being given closer study by the man in charge of automotive equipment than that of the high rate of turnover of mechanical labor. Some ways of meeting the difficulty, as suggested by the speaker, are to secure the best available material for apprentices and helpers, to train them and pay them while learning, and when they have acquired proficiency to pay them the wage scale. They will in turn pay dividends on investments in them; cheap labor results in poor work and cheap mechanics in repetition of work.

Good Shop Equipment and System Needed

Having built up an organization, the operator was urged by Mr. Wood to have personal contact with it, as this is his most valuable asset and a contented personnel means lower cost per mile. To do good work, the mechanic needs sufficient and proper tools, therefore the equipment of a shop must be so designed that skill of the mechanic is not an important factor in the time required to do a job. Tools should be as simple as possible and their installation must be followed by careful instructions as to their use to the best advantage. Special attention was called by the speaker to the fact that a small staff adequately provided with precision and other tools is a far better investment than a large and changing staff so equipped, and the more the men are relieved from muscular exertion in handling parts, the more efficient they are in the finer operations, hence the substitution of mechanical devices for the heavy work means quicker returns.

Order and system in a shop are imperative in the maintenance of low operating costs for motor-vehicles. The mechanic's time is wasted when he cannot lay his hand on the tool he wants, and the cost of the time goes into the maintenance expense. A system of maintaining data on each unit that has resulted in the saving of 12 per cent in the maintenance cost for one fleet operator was cited as an example of system in connection with operating costs. A unit control board shows the type of unit and the number of days it is idle; records show the number of days the unit is in the repair-shop and the regularity of oiling and greasing; and the inspection system takes care of minor troubles before they become serious and also includes records of man-hours spent on the units and of parts repaired.

Hilly topography of some of the coast cities, such as San Francisco and Seattle, were mentioned as a factor in the increase in cost of truck operation.

Coast Repair-Shop Practices Summarized

The last part of Mr. Wood's paper was devoted to a summary of repair-shop practice followed by large-fleet operators on the coast and to a description of a somewhat recent development in the direction of the substitution for distillate of mild chemical cleaners in powdered form, which has eliminated the fire hazard and resulted in greater shop cleanliness. Cost figures on steam cleaning, washing and polishing vehicles were given and in conclusion Mr. Wood stated that, in the endeavor of operators to secure reliability of the vehicles, the dynamometer is rapidly taking its place in the commercial field and will in time revolutionize shop practices on the Pacific Coast, as it is a great aid to the fleet operator in solving many of his operation and maintenance problems.

Repair-shop practice followed by large-fleet operators on the coast, as shown by questionnaires returned to the West Coast Committee on Operation and Maintenance, were summarized by Mr. Wood. The questionnaires showed that five operators regard it necessary to overhaul trucks annually, while others give them an overhauling whenever it is thought necessary on a mileage basis or as a result of inspection or reports from the shop forces. These periods range from 1½ to 4 years. Light trucks such as the Ford and Dodge are treated on the same basis as the larger trucks, but passenger cars of these makes when overhauled are treated on a mileage or condition basis or are traded-in after running from 40,000 to 50,000 miles.

Eight operators believe that the proper way to refinish cylinder-blocks is to regrind the bores, but two operators rebore and hone them. The use of mechanical devices for refinishing bearings does not seem practical for small jobs but is regarded as necessary in shops handling a large volume of work. The reamer type for main bearings is most used. Connecting-rod bearings are as a rule reamed and scraped by hand, but such mechanical devices as are used are mostly of the fly-cutter type. Running-in time of engines after overhauling varies from 2 to 8 hr. Sixteen operators use the unit-repair system for engines, principally on Ford and Dodge vehicles, but to be successful this system is suitable only with large fleets.

Seven fleet operators employ inspectors and it is a general rule that the inspector takes care of adjustments and light or emergency repair-work. Inspection periods vary from a week to a year, according to the class of work done by the inspectors. Only three of the operators who returned questionnaires use regular inspection forms. Trouble shooting and engine work are done by specialists for six fleet operators who, as a rule, employ apprentices rather than helpers or handy men.

Steam-cleaning plants are regarded as a necessity in the larger garages, which also use overhead cranes, according to the speaker, whereas portable cranes are used in the smaller shops. Repair pits of the closed-end type are used to a considerable extent. Only one operator furnishes his workmen with hand tools.

Magnitude of the Maintenance Industry

The automotive maintenance business has been somewhat neglected by executives in the industry, and too much burden has been cast upon the transportation superintendent and the shop foreman, in the judgment of the Automotive Equipment Association, said Mr. Goldman, who gave the highlights of his paper instead of reading it verbatim. The organization of which he is secretary is composed of about 600 manufacturers and wholesalers of shop equipment, service parts, and accessories and is therefore vitally interested in all methods that apply to automotive maintenance, as the marketing of their products is dependent upon expansion of the market for them. Hence, some of the members volunteered to set up working exhibits of their newest equipment and methods and placed in charge of them, not salesmen, but men capable of answering questions as to cost of performance, time required to do a job, the operating experience necessary and the like.

Methods in use today have become outstandingly important, asserted Mr. Goldman, not only in the matter of maintenance but in the activities of selling; and to illustrate this idea he cited the supersession of the old-time corner grocer, who depended for success upon his personality and contact with customers, by the chain and help-yourself grocery

stores, which can employ mediocre clerks but the methods of which are acceptable to the public. Without attempting to tell how new methods are produced or whence they come, the speaker stated that he had been much impressed by a statement made a few days previously by James H. Collins that the aggregate expenditure last year for maintenance of automotive transportation was $1,202,000,000 as against a total expenditure of $541,000,000 for new vehicles. An industry representing so vast an expenditure is worth very careful research as to methods, he said.

Many evolutions have occurred in service equipment, but some outstanding conditions have been almost overlooked. One is the idle time of transportation equipment. Mr. Goldman stated that in a conference shortly before with a fleet-operating member of the Society, after calculating interest on investment, loss of earning, storage in the service station, depreciation on the vehicle, and floor space in the garage apportioned on the yearly basis, the idle time of a vehicle was found to be $1.15 per hr. The operator found that, on this basis, he could save money by having done in his own establishment many service jobs that theretofore had been sent to an outside service station, as, instead of being out of service for 24 hr., the vehicle could be returned to work in 6 or 8 hr. by his own organization.

Discussion on Army Maintenance System

Discussion on Lieutenant Thee's paper related mainly to the relative cost of repair work in the Army depots and in outside shops. The author expressed the conviction that the cost of doing work in the Army repair-shops is much lower. This has been investigated very carefully at Camp Holabird and it has been shown that the present system is the more economical. The average cost of virtually every operation is known. The corps area at Boston endeavors to anticipate its requirements of replacements and to get the necessary material from Camp Holabird to avoid sending repair work outside. Under the unit-replacement system, if an engine becomes unserviceable and mechanics and facilities for making repairs are not available at the Boston shops, the engine is shipped to Camp Holabird. A 10-per cent reserve stock of engines for Class-B trucks is maintained and the unserviceable engine is replaced by one out of reserve.

Asked by F. C. Horner, of the General Motors Corporation, what system of transportation is used between the main supply base at Camp Holabird and various Army posts throughout the Country, Lieutenant Thee replied that rail, water and other systems are used. Most shipments go by steamship, but carload lots are shipped by rail as the railroad goes right to Camp Holabird, whereas shipments by water require a 5-mile haul to the docks. Officers in charge are not concerned with economy but with getting results at the proper time. In event of a vehicle becoming so unserviceable that the cost of repairing it will exceed 35 per cent of its original cost, the vehicle is surveyed and sold by the salvage officer.

TRANSPORTATION MEETING TECHNICAL PROGRAM

Maintenance Session

Tuesday, Oct. 25

J. F. Winchester, Chairman
(Standard Oil Co. of N. J.)

Army System of Maintenance—Lieut. W. C. Thee, Quartermaster Corps, U. S. A.

Maintenance on the West Coast—E. C. Wood, Pacific Gas & Electric Co.

Shop Equipment and Tools—Martin E. Goldman, Automotive Equipment Association

Operation and Maintenance Committee Session

R. E. Plimpton, Chairman
(*Bus Transportation*)

West Coast Subcommittee Report—E. C. Wood, Pacific Gas & Electric Co.

Nomenclature Subcommittee Report—F. K. Glynn, American Telephone & Telegraph Co.

Accounting Subcommittee Report—R. E. Plimpton, *Bus Transportation*

Regulations Subcommittee Report—F. J. Scarr, Scarr Transportation Service

Freight-Handling Session

Wednesday, Oct. 26

J. J. Mantell, Chairman

General Theory of Containers—Bernard Allen, Scarr Transportation Service—Read by F. J. Scarr

Tractor - Trailer - Container Terminal Handling of Freight—M. T. Hanrahan, American Railway Express Co.

Motor-Truck Session

Wednesday, Oct. 26—Continued

F. C. Horner, Chairman
(General Motors Corporation)

Supervision of Motor-Vehicle Transportation at Long Distances—G. R. Gwynne, Continental Oil Co.—Read by F. K. Glynn

Truck Operation on the West Coast—E. C. Wood, Pacific Gas & Electric Co.

Application of Operating Cost Systems—A. W. S. Herrington, Consulting Engineer

Common-Carrier Trucking Under State Regulations—E. L. Murphy, Jr., Murphy Transportation Co.

Coordinated Rail and Motor-Truck Transportation—George W. Dixon, Arthur Dixon Transfer Co.—Read by F. C. Horner

Rail-Car and Motorcoach Session

Thursday, Oct. 27

H. C. Crowell, Chairman
(Pennsylvania Railroad)

Morning Program

Rail-Car Design and Operation—W. C. Sanders, Timken Roller Bearing Co.—Read by M. S. Downes

Rail-Car Fuels—E. Wanamaker, Chicago, Rock Island & Pacific Railway Co.

Rail-Car or Motorcoach, the Economic Field of Each—H. F. Fritch, Boston & Maine Railroad

Afternoon Program

Motorcoach Design—K. J. Ammerman, American Car & Foundry Motors Co.

Motorcoach Operation on the West Coach—E. C. Wood, Pacific Gas & Electric Co.

Today's Motorcoach Legislation—R. H. Newcomb, New York, New Haven & Hartford Railroad—Read by F. J. Scarr

Tomorrow's Motorcoach Legislation—A. M. Hill, Midland Trail Transit Co.—Read by C. G. Moore

F. K. Glynn, of the American Telephone & Telegraph Co., asked if interest on investment is taken into consideration, and Lieutenant Thee replied that military supplies cannot be regarded in the same light as in civil operations but that the item of interest is taken into account. However, the Army is operating surplus war material such as the Class-B 3-ton truck, which is still serviceable but for which not more than $800 to $1,500 could be realized if it were sold. With the large supply of spare parts on hand, and as the repair work is done by soldier labor, it is believed to be economical to continue these trucks in operation. He said that truck designs have not changed a great deal since they were built and that trouble is not being experienced with the engine, the transmission or the differential. Not a single truck tire has been purchased since the war, he said, and a great many are still on hand.

The Army had a large supply of Cadillac engines at the close of the war and converted them for use in tractors; it has had to buy very few parts for these engines.

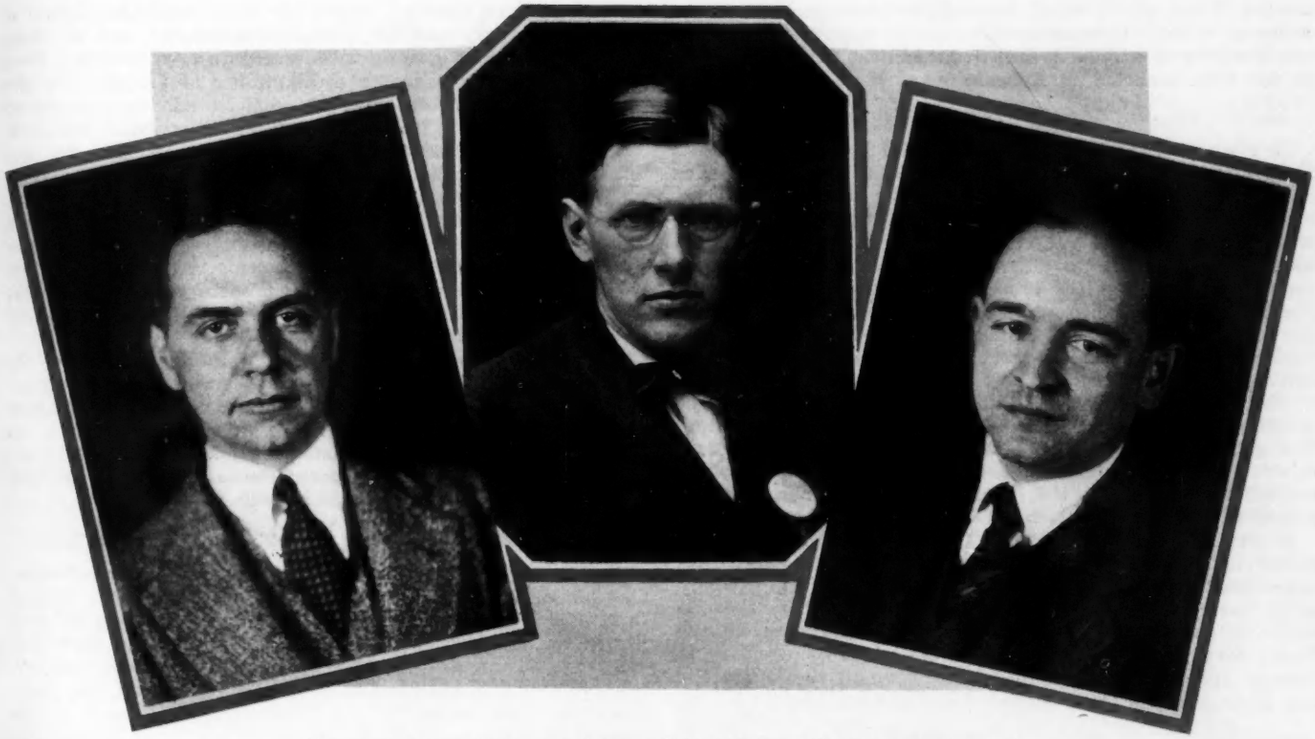
Charts Show Big Operating-Cost Reduction

With reference to Mr. Wood's paper, A. J. Scaife, of the White Motor Co., remarked that he did not clearly understand the significance of some of the figures in one of the charts, and Mr. Wood explained that they represented man-hours expended on completed work orders on various component parts in different shops in San Francisco, Oakland, Los Angeles, and in Portland, Ore. F. C. Horner, of the General Motors Corporation, expressed similar uncertainty regarding another chart and Mr. Wood stated that the figures represented cost per mile for operating the equipment of 16 operators who organized the Corporation of Automotive Engineers in California in 1923. These men operate about $26,000,000 worth of automotive equipment. In 1924 they began plotting the figures on completed work orders on various classes of vehicle and to discuss the reasons for some of the costs, and found that effective savings could be realized by installing better shop equipment and practices. Maintenance cost alone on light passenger-vehicles was reduced from 20 cents in 1923 to about 2 cents per mile in 1927. Some of this reduction was due to replacement of vehicles that had been operating for 6 years.

Replying to W. A. McCutcheon, of the West Penn Power Co., Mr. Wood said responsibility for following up the chart is placed upon the shop foreman, who has a blackboard on which the work of each day is chalked. Since the installation of this system it has not been necessary to buy spare trucks, automobiles or unit parts, as it was possible to increase the load factor on each of the units. The chart shows what units are in the shop for repair, the number

THE CHAIRMAN AND SPEAKERS AT THE MAINTENANCE SESSION

J. F. Winchester (Top), Who Presided; E. C. Wood (Left), Who Discussed Maintenance Practices on the West Coast; Lieut. W. C. Thee (Right), Who Discussed the Army System of Maintenance; and Martin E. Goldman (Lower Center), Who Discussed Shop Equipment and Tools



MEMBERS WHO TOOK AN ACTIVE PART IN THE COMMITTEE SESSION

R. E. Plimpton (Center), Chairman of the Operation and Maintenance Committee, Who Presided at the Session; F. K. Glynn (Right), Who Presented the Subcommittee Report on Nomenclature; and J. H. Watrous (Left)

of days each is in the shop, and when a vehicle or body is in the paint shop. At the end of the month the information is tabulated.

An attempt is now being made in all the shops, said Mr. Wood, to standardize on a cost-accounting system that will show the number of work-hours expended on each component part.

In closing the discussion, Chairman Winchester reminded the members that discussion for which there was insufficient time at the session can be written and submitted to the Society's office for inclusion in the Operation and Maintenance Department of THE JOURNAL.

REPORTS OF COMMITTEES

Operation and Maintenance Committee Session Receives and Discusses Them

This session, devoted to the presentation and discussion of the first formal reports of the Operation and Maintenance Committee and its subcommittees, was well attended by transportation representatives and members from the motor-vehicle manufacturers who displayed marked interest in the reports. R. E. Plimpton, Chairman of the Committee and of its Subcommittee on Accounting, presided and gave the reports of his committees, tracing the development of their organization and work, outlining what has been accomplished to the present time and what it is expected will be accomplished in the future.

COSTS A SUBJECT OF PRIME IMPORTANCE

It was evident from the discussion of the reports dealing with the determining and recording of motor-vehicle operation and maintenance costs that were given by Mr. Plimpton and E. C. Wood, Chairman of the West Coast Subcommittee, that this subject is of prime importance to motor-transport operators, who at present have no uniform system on which to make cost analyses of their operations or comparisons with other operators. Mr. Wood also reported the results of an extensive investigation made among motor-vehicle operators in the Pacific Coast States of the relation of present vehicle design and construction to the maintenance required on the vehicles. His report discussed the details of construction and offered suggestions of a general nature as to lines along which designs should be developed to improve the vehicles for the classes of work they have to do and to reduce their costs of operation and maintenance.

A. J. Scaife and F. A. Whitten indicated in the discussion that these suggestions are of much value but that the vehicle manufacturers can incorporate such changes in their vehicles only gradually, that many of the troubles mentioned are known and that it is expected they will eventually be largely remedied.

SCOPE OF SUBCOMMITTEE ON REGULATION DEFINED

The report of the Subcommittee on Motor-Vehicle Regulation, given by Chairman F. J. Scarr, referred to the existing lack of consistency of motor-vehicle regulations and laws in various States, the plan of the subcommittee to study them only insofar as their engineering phases are concerned, and to act only in an advisory capacity with organizations whose purposes and activities relate to the enacting and enforcing of regulations and legislation.

Some opinion was expressed that the Society, as an engineering body, should not concern itself with regulations or legislation, but discussion indicated that these have a direct effect on vehicle engineering as well as on vehicle operation, and led to an elaborated defining of the subcommittee's purpose and scope.

TO DEVELOP STANDARD ACCOUNTING NOMENCLATURE

F. K. Glynn's report for the Subcommittee on Nomenclature pointed out the diversified use of terms used for various phases of maintenance and operation and the need for a systematic listing of such terms and a definition for each to show clearly what it means. Mr. Glynn also stated that the subcommittee plans to obtain lists of terms used by a large group of prominent operating companies, their definitions of such terms and those for which definitions are

wanted, from all of which the subcommittee expects to develop a standard nomenclature. It is expected that this work will be of particular importance in the future activities of the Subcommittee on Accounting.

Report on Mechanical Information Sheets Soon

In giving his report for the Mechanical Information Sheets Subcommittee, Chairman J. F. Winchester stated that such records of detail mechanical specifications for vehicles are of specific value to motor-vehicle operators in connection with the maintenance of relatively old or orphan vehicles, and that he anticipates having definite recommendations to report by the end of the present administrative year of the Society. He also reviewed briefly the pioneering work of the lately deceased Past-President Charles M. Manly in promoting the motor-vehicle-fleet operation and maintenance activities of the Society and referred to the increasing growth in this class of the membership as well as its importance in the automotive field. Mr. Winchester also suggested that this group of members should now take an active part in other activities, such as standardization, and that they should be well represented on the divisions of the Standards Committee and other committees of the Society.

In the absence of Chairman E. Favary, of the Subcommittee on Education, Mr. Plimpton referred to that subcommittee's plan to have all of the Sections of the Society carry through a definite and uniform program to develop active interest in operation and maintenance work in different parts of the Country. The reports and the discussions thereon are scheduled for printing in full in the Operation and Maintenance department of The Journal later.

CONTAINER IMPORTANCE EMPHASIZED

Freight-Handling Session Also Told of Trailer Use Here and Abroad

At the Freight-Handling Session, Wednesday morning, Oct. 26, J. J. Mantell, formerly vice-president of the Erie Railroad Co., presided and opened the session with some remarks from his 25 years of experience in New York City, where he was terminal manager in charge of the port for the United States Railroad Administration during the war.

Owing to the congestion below 14th Street in New York City, it costs the railroads as much to handle the freight from the outer classification yards within 7 miles of City Hall as it does to load that freight at Buffalo and transport it to the classification yards, according to Mr. Mantell. Freight arriving at seaboard is handled from two to five times and nobody knows how many million dollars is spent in rehandling freight on the railroads.

Most shippers are handling their freight just as they did 50 years ago. Because of the congestion at the railroad piers, a shipper's truck can seldom make more than two round trips per day and sometimes spends a whole day without being able to get a load. This condition has been met in one case with which Mr. Mantell was connected by securing an inland station from which the freight is delivered directly to the consignee by motor-truck.

Container History and Advantages

In the absence of Bernard Allen, of the Scarr Transportation Service, his paper on the General Theory of Container Use was read by F. J. Scarr. The history of the container on railroads dates back to an English patent issued in 1845 for a container that could be used for freight on wide or narrow-gage railroad cars or on horse drays. The containers were used also in other European countries. Patents were issued in Italy and in France under dates of 1879 and 1887 respectively, according to Mr. Allen.

In 1910 an extensive use of containers for less-than-carload freight, which was proposed to the Board of Trade in London, was the subject of much investigation and controversy. It was estimated that the undertaking would involve a prewar cost of $1,500,000,000, and it was definitely rejected.

Unit containers are being operated in the United States on the New York Central, the West Shore and the Boston & Maine railroads and by other organizations, one of them loading household goods for shipment to any country. They effect savings by reducing the handling of freight, the idle time of comparatively expensive vehicles and the amount of crating required. They are justified only when the total work of transportation is done at a less cost than by any other method or when they expedite the operation.

The greatest economy to the railroad results from a reduction in the number of handlings for individual packages from six to two. Further economies result where transfers are necessary. Car efficiency is increased, terminal congestion is reduced, and theft and damage claims are eliminated. The shipper benefits from faster handling and a reduction in packing, crating and cartage costs.

Mr. Allen recommends that two sizes of container be standardized so that they will adapt themselves to the standard railroad equipment and to transportation on standard motor-trucks. The basic function of the container is to afford a cheap means of transferring goods from one transportation facility to the other, so that each may be utilized to do the work for which it is best fitted.

Interterminal Freight Handling with Trailers

Following Mr. Allen's paper was one on Tractor-Trailer-Container Terminal-Handling of Freight, by M. T. Hanrahan, who operates the fleet of the American Railway Express Co. in Chicago. He said that what formerly had been considered fast service suffered by comparison when motor-trucks were introduced, but the motor-truck did not fully meet the requirements of economy in handling loads transferred between stations, because its power unit was idle during long periods of loading and unloading.

This condition finally led to the use in 1921 of 5 tractors and 15 semi-trailers for this service. They proved well adapted to the work, providing economy of terminal space, haulage expense and time; and incidental economy resulted from the possibility of sealing trailer loads. Now 45 tractors and 105 trailers are in this service.

Hauling and spotting trailers is the whole duty of the chauffeur. The loading and unloading is done entirely by terminal forces except in case of deliveries to large individual receivers. Coupling and uncoupling of the trailer, including the operation of its brakes and front supporting wheels, can be done by the chauffeur without leaving his cab.

The control of the units is made possible by a board showing the location of each as it is reported to the despatcher. A numbered peg represents each trailer and the despatcher moves the peg to show whether the trailer is en route or standing at a terminal; and whether it is loaded, loading, unloading or empty. When one terminal calls for empty trailers, the despatcher hurries the transfer of trailers from other points with loads for that terminal. This reduces the movement of empties. Any variation from a rigid driving schedule must be accounted for by the chauffeurs.

Approximately 65 per cent of the total moves are made with loads, but not all of these are capacity loads. The average loaded moves per tractor in 8 hr. during the last 4 years have been 13¼. The fleet is operated in three daily shifts of 8 hr. each, one change being made on the street and the other two in the garage, where cars may be given gasoline, oil and the necessary mechanical attention.

Mr. Hanrahan enumerated a number of advantages in the use of this equipment for this work, but said that the system is not readily adaptable to all cartage problems and therefore each situation should be studied carefully before such service is installed.

How Containers Are Used in England

Owing to the large amount of experience he has had in the operation of containers, the address of W. H. Gaunt, manager of traffic arrangements of J. Lyons & Co., a large distributor of food products in England, was of great interest. Mr. Gaunt, who is also an official and committee head of organizations of British shipping interests, said that containers have been used in the British cotton trade for many

years to save handling of goods at transfer points, particularly in the Lancashire district, where a flat platform is used to carry a load about 6 ft. high and is lifted by rings at each corner and transported by railroad or truck. The loads are covered with tarpaulins in transit and the trucking is done by the railroads.

Before the coming of motor-trucks, furniture moving was done with lift vans, which are boxes with sling attachments, that can be loaded at the house, taken to the railroad station by the moving firm, and consigned to agents of the firm who will unload the goods at their destination. Large importers use lighter containers for transporting fruit and flowers from Jersey and other island ports to London and Southampton, where they are taken to the markets by horse-drawn vehicles. Containers are used also in transporting coal from the collieries. All these containers are provided by the shippers, and freight must be paid on both contents and container, including any transportation of the empty container.

Duralumin Bodies Found Economical

The traffic of Mr. Gaunt's organization extends to many of the large towns in England. It represents 10,000,000 meals in the course of 1 week and consists chiefly of small packages of foodstuffs. For a number of years containers were built of wood and strap iron with a door at one end, the tare weight amounting to about one-third of the net weight. These are now being replaced by duralumin containers of less than half the weight of the older ones. They cost much more than the older type, but the saving in freight expense is enough to repay the total cost within 18 months. The Lyons firm now has about 100 duralumin containers in service. The first was built in 1920 and is still at work. They are used to some extent by other firms in England.

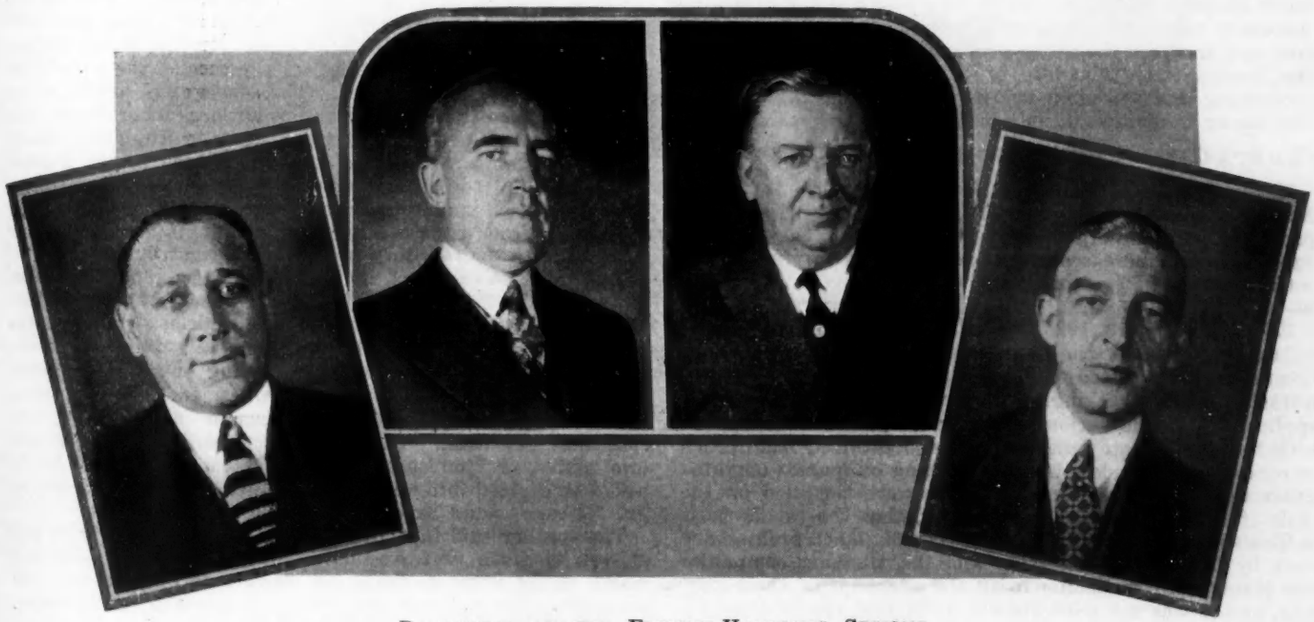
Containers for sea shipment are provided with an underframe of zinc or other metal to guard against corrosion. Care is required in loading because a piece of loose wood resting against the container is likely to wear a hole, although the material will stand a great deal of shock and other kinds of abuse. This liability to abrasion might be a serious objection in the use of a container as a common carrier. Common use also would be objectionable in the Lyons case because foodstuffs must be protected from objectionable odors. Mr. Gaunt did not recommend this particular type of container for universal use, because of this and other reasons, but said that it may be useful in many cases.

The semi-trailer is little used in England, but the four-wheel trailer following a truck is used more than in America. This requires a man beside the chauffeur to couple and uncouple, as difficulty is encountered in backing. Mr. Gaunt expressed much interest in the semi-trailer and said that he intended to try it for one of his haulage problems.

LIVE FACTORS OF MOTOR-TRUCKING

Operation, Supervision, Cost Systems, Regulation, and Coordination Featured

Important papers replete with data needed not only by those directly interested in the foregoing subjects but by automotive engineers generally were presented at the motor-truck session, held Wednesday afternoon, Oct. 26. The diversity of subjects, as applied to the motor-truck alone and without consideration of them in their application to other motor-vehicles, is another indication of the broad scope of the operation and maintenance problem. F. C. Horner, of the General Motors Corporation, presided as chairman.



Discussers at the Freight-Handling Session

J. J. Mantell (Upper Left), Who Presided at the Freight-Handling Session; M. T. Hanrahan (Upper Right), Who Discussed Tractor-Trailer-Container Terminal Handling of Freight; G. E. Sick (Lower Left) and J. B. Beattie (Lower Right), Who Discussed the Papers

In his paper on motor-truck operating-conditions on the Pacific Coast and the apparent trends in changes of design to meet existent and future conditions, Edwin C. Wood, superintendent of transportation for the Pacific Gas & Electric Co., San Francisco, said in part that the important outstanding subjects now being considered are pneumatic tires for heavy-duty trucks, six-wheel trucks, four-wheel drives, six-cylinder-engine installation, and additional change-speeds. The development of long-distance hauling on the Pacific Coast has created a new phase of transportation. Heavy trucks must go where ideal road-conditions do not exist and where they encounter steep grades. These conditions demand better motor-truck performance and this in turn calls for greater engine-power, additional transmission-speeds, better brakes and better control. Larger factors of safety are needed. Over-drive is in demand for the lighter trucks. High road-speed maintained seems to create a tendency toward reduction of the unsprung weight of the chassis and a need for better lubrication. The speaker also entered into considerable detail regarding special types of equipment already in operation for special purposes, such as refrigeration service for perishable products, and concerning special phases of operation.

Supervision of Motor-Vehicle Transportation

The paper by George R. Gwynne, chief automotive engineer for the Continental Oil Co., Denver, carried the foregoing title and dealt with the supervising practices of the company mentioned, which refines and markets petroleum products in numerous Western States. To facilitate supervision, the company has established so-called motor-equipment divisions located in the large Western cities and has provided a "base shop" at each of these locations. "Sub-base shops" have been established also in isolated parts of the company's territory, and these are operated under the direction of the superintendent of the base shop of the division in which they may be located. Headquarters for traveling inspectors are also provided in each of the divisions.

Mr. Gwynne showed numerous lantern slides illustrative of the types of vehicle operated by the company and of the conditions under which they operate in the different States, and also gave details of the maintenance methods practised.

Application of Operating-Cost System

In his paper on Using Truck-Operating Costs To Increase Delivery Efficiency, A. W. Herrington, consulting engineer, City of Washington, cited a supposed company in the retail dairy business having a fleet of 30 vehicles, assumed definite monetary values for the several factors constituting the total cost, and analyzed the entire problem in a way to demonstrate the fundamental principles of a comprehensive system of accounting that will make evident all the information sought. The paper is printed in full in this issue of The Journal.

Common-Carrier Trucking Under State Regulations

This subject was presented by E. L. Murphy, Jr., of the Murphy Transfer & Storage Co., Minneapolis, who said in part that, since he organized the company 17 years ago, the equipment has increased from one horse-drawn truck to become a fleet of 175 motor-trucks which operate in Minneapolis and St. Paul.

Effective April 13, 1925, the Minnesota Legislature passed a law under which the Minnesota Railroad & Warehouse Commission was vested with the power to direct and regulate intrastate motor-trucking. This law called for the filing of applications by the various trucking companies in connection with their intrastate hauling, and also involved motorcoach transportation. Under the law, trucking companies operated under tentative agreements. Tariffs were compiled on the basis of mileage and the law specified that the tariffs must be filed with the Commission for approval. Much preliminary work by both the Commission and the trucking companies was involved in connection with the granting of these permits, and it was not until June 3, 1927, that the first permit to a trucking company was issued. The long delay in the actual issuance of permits was due also to the fact that the attention of the Commission was given to hearings in connection with motorcoach transportation.

Mr. Murphy said also that, under the ruling of the Commission, the equipment of a trucking company must meet certain requirements. The bookkeeping system used by his company was devised and installed under order of the Commission and is subject to inspection at any time. In practice, the books are checked by the Commission several times each year. All trucks doing intrastate hauling are subject to a tax of 10 per cent on their total cost; for example, if a chassis costs $6,000 and the body costs $1,500, the license to operate the truck would cost $750. The speaker remarked further that relations with the Commission have been harmonious.

Coordinated Rail and Truck Transportation

Owing to the absence of George V. Dixon, of the Arthur Dixon Transfer Co., Chicago, whose paper on Coordinated Rail and Motor-Truck Transportation was originally intended for presentation at the Transportation Banquet, the paper was read in outline form at this session by Chairman Horner.

The author cited five principal uses for the motor-truck in the movement of less-than-carload freight that seem feasible; and two other uses which he understands are now being considered seriously. They are:

(1) Station-to-station haul within well-defined limits of distance, instead of the use of peddler trains
(2) Hauling from small to larger stations to effect the concentration of freight in through cars
(3) Hauling from a central delivery-point to smaller stations for final delivery to the consignee
(4) Interchange between railroads and boat lines, and cartage to replace lighterage
(5) Hauling to and from the transfer platform to the various designated delivery-points

The other two uses mentioned are (*a*) hauling direct from industries to transfer platforms to eliminate switching delays met in the movement of industrial trap-cars and (*b*) the hauling of standardized containers for certain classes of merchandise to permit unit shipments to designated points. The paper then went on to present short analyses of the foregoing items.

Features of the Discussion

Following the presentation of the papers, W. H. Gaunt, of London, England, gave some of his impressions of motor-vehicle operation in America as compared with English practice. He emphasized that the conditions here are very different from those in England where, for this reason largely, the subject of maintenance of commercial motor-vehicles is not so highly systematized. The topography of the country is not so diversified and the conditions under which the vehicles operate are more nearly uniform in England. Many of the companies are rather similar to those in the United States, such as the oil companies, and have similar problems. They carry out maintenance and repair work along similar lines, but, from a maintenance standpoint, it is much easier to operate in the territory in which they distribute.

Referring to the work of the company he represents, Mr. Gaunt said that it operates approximately 1000 motor-vehicles and about 450 horse-drawn vehicles. Representatives of the company call on approximately 200,000 dealers each week in connection with the selling of different kinds of groceries in packet form. The salesmen take the goods from a central depot, and each salesman calls on, say, 300 customers per week. The cities and towns are mapped out into routes, or "journeys." A city of the size of St. Louis would be divided into about 25 so-called journeys, and a city like Chicago would have about 70.

The speaker said that, of necessity, the sales ability of the drivers is given first consideration, although the company makes every effort to train the drivers to operate vehicles properly. The vehicles are inspected every 5 or 6 weeks. The reports of the inspectors are made in triplicate, and the sales chief, the superintendent of the garage service, and the management has a copy each. If a driver maintains his vehicle in good condition, he is paid a bonus.

In reply to a question asked by Mr. Gaunt as to the relative merits of the electric-vehicle and the gasoline-engine motor-vehicle, A. W. Herrington said that for limited service, such as the delivery of milk, there is little difference between them. In the small sizes, the higher initial cost added to the investment in carrying equipment of the electric vehicle will offset the lower cost per mile of operation and will bring the actual cost of operation of the two practically to a balance.

H. C. Crowell and G. E. Sick, of the Pennsylvania Railroad, outlined the present status of the railroad with regard to coordination between the railroad and the motor-vehicle services. The general coordination program was approached from three directions: first, the elimination of local freight-train service and the substitution of motor-vehicle highway-service; second, terminal operation in which motor-vehicle equipment is used for transport purposes in lieu of trap-car service; and third, so-called store-door delivery.

Other subjects discussed included governmental regulation of the motor-truck, the so-called fly-by-night operation of motor-vehicles as compared with legitimate stable operation by a reliable company, and rulings of the courts as to what determines whether a company is a "common carrier."

AMONG THOSE PRESENT AT THE MOTOR-TRUCK SESSION WERE

F. C. Horner (Top), Who Presided at the Session; A. W. Herrington (Right), Who Discussed the Application of Operating Cost Systems; E. L. Murphy, Jr. (Left), Who Discussed Common-Carrier Trucking under State Regulations, and H. E. Barber, of the Egyptian Transportation System

A further interesting feature was the description given by Mr. Gaunt of the heavy-duty steam-driven vehicles used in England. They weigh from 4 to 6 tons, are equipped with rubber tires and are capable of a speed of say 16 m.p.h. Within their limitations, Mr. Gaunt said these vehicles are very effective and satisfactory.

BANQUET HUMOR AND SERIOUSNESS

Distinguished Speakers Tell about Land and Air Transport Here and Abroad

Humor and seriousness were intermingled delightfully at the Transportation Banquet held Wednesday night, Oct. 26, in connection with the Automotive Transportation Meeting. The occasion was more than usually favored by distinguished and excellent speakers and by the wide range of their addresses, which dealt with transportation in its broad aspects by rail, by highway and by air both in this Country and in England and in civil and military operations. Harmony of views and great good-will toward other means of transportation were made manifest in the addresses from men variously connected with the several means of mechanical transportation, the belief obviously held in common being that the field of transportation is so vast that each means has its place and will continue to function, and that automotive transportation both by land and by air will supplant and be correlated with the great service rendered by the railroads.

So that all the attendants might know at the start who the men at the speakers' table were, Chairman F. J. Scarr, of the Transportation Meeting Committee, introduced them as follows:

R. E. Plimpton, associate editor of *Bus Transportation* and chairman of the Operation and Maintenance Committee.

E. C. Newcomb, consulting engineer of the Studebaker Corporation of America.

H. F. Fritch, passenger traffic manager of the Boston & Maine Railroad.

Col. R. W. Gunney, U. S. A., of the Sixth Army Corps Area.

Col. George Ball, U. S. A., of the Sixth Army Corps Area.

F. C. Horner, assistant to the vice-president of the General Motors Corporation.

J. D. Fitzgerald, of the Pennsylvania Railroad Co.

E. C. Wood, superintendent of transportation for the Pacific Gas & Electric Co. and Chairman of the West Coast Subcommittee of the Operation and Maintenance Committee.

C. W. Luthman, of the Atchison, Topeka & Santa Fe Railway Co.

J. H. Hunt, of the Chevrolet Motor Co. and president of the Society.

OPERATORS WELCOMED AND ASSURED OF INTEREST

Asked by the Chairman to extend a few words of welcome to the guests and members, J. W. Tierney, chairman of the Chicago Section, referred humorously to the agitation of Chicago's chief executive over the taint of un-Americanism in the Chicago public schools and the public library, and offered a word of caution from a native to the stranger within the gates, suggesting that no reference be made in the meeting to Ricardo or to the Lanchester balancer and that mention of king-pins, the crown of fenders, princ-iples and the like be eliminated from the S.A.E. HANDBOOK to avoid the casting of the volume upon a lake-front pyre.

President Hunt assured the gathering that the interest which the Council and the Society feels in the transportation group bears no relation to the proportion borne by this group to the total membership but that it is important beyond its numerical strength. In the case of mass transportation, success is measured by the problems the Society is working on and that are involved in the issue, he said. The reaction that the operating men can give is needed tremendously in the design engineer's work and will be increasingly needed in the future. On behalf of the Council, Mr. Hunt thanked the special committee that arranged the Transportation Meeting and which had done a splendid job. He was glad, he said, that so many railroad men were in attendance, as there was a time when some railroad men felt that the automotive developments represented a type of competition that was at least unfortunate; but, taken by and large, the traffic that has been created for the railroads by them has more than counterbalanced any traffic that motor-vehicles have taken from the railroads. In the handling of goods and rendering of services in bulk, it has been found that the two interests have a problem in common, and that progress is going to be made by cooperation.

In conclusion, President Hunt introduced, as toastmaster of the banquet, T. C. Powell, of the Chicago & Eastern Illinois Railway Co.

Why Conventions and Banquets?

Thinking back over the many similar gatherings of organizations which he had attended, with the query in mind, Why is a convention and why is a banquet?, he came to the conclusion, said Mr. Powell, that they are held simply because men want them. The benefit of a convention is that it brings together men from all over the Country so that the ideas of the man from Oregon and the man from Maine can be interchanged to mutual advantage. The contacts made broaden ideas, and these contacts and the associations formed make the Country what it is. While the spirit of American business men is closely connected throughout the Country by means of communication such as the telegraph, the telephone and the radio, and the quicker means of transportation by airplane, the actual value of a convention lies in bringing men together.

Speaking as a railroad man, Mr. Powell said that the railroad was the first to operate an automotive vehicle and that the steam engine that ran on the Stockton & Darlington Railroad was the one that made the automotive vehicle a success. He was sure, he asserted, that all now realize that the transportation movement is cooperative and that the two interests are not opposed. As evidence of this, he introduced W. H. Gaunt, of J. Lyons & Co., Ltd., of London, and vice-president of the Institute of Motor Transport in England.

Accessibility to Centers Good for Public

However clever business may have been in adapting itself to modern conditions, said Mr. Gaunt, it can be said that it has shaped itself and arrived at its present position through taking advantage of improved means of transportation that the railroad and motor transport have brought about in the last 30 years. He explained the organization of the British Institute of Transport, which was founded with the definite idea of bringing together and obtaining a more thorough understanding among the men in the transportation lines and which has arrived at a very satisfactory membership. After functioning for several years, it felt that the time had arrived when the lower grades of membership should be recruited from men who had passed a qualification, and it is now gradually getting to the position of making membership, particularly among the younger men, some sort of test through a fairly comprehensive range of transport subjects. The man who passes two preliminary examinations and qualifies is mentally prepared to have tolerance for each branch of the transport business.

Great changes brought about in America by motor transport have been of much interest to him during his present visit to Canada and the United States, and one of these that impressed him has been the extension of mail-order houses due to the fact that probably 90 per cent of the people are within easy distance of a main highway and find it easy to drive in to local centers to make purchases. The mail-order houses, like the large chain-store companies, are therefore establishing branches in the country towns. It is a good thing for the Nation and a sign of progress that fewer people now live in inaccessible places.

Transport Conditions in England

Depressed economic conditions in England have adversely affected the automotive and transportation industries in England as compared with prosperity in this Country, but the commercial vehicle and motorcoach companies have done extremely well, Mr. Gaunt told his hearers. The small operators of such vehicles have been washed out by or swept into huge systems of motor transport spreading over large areas of the country. The solution of this problem seems somewhat distant. Last year the transportation systems of London carried 3,252,000,000 passengers and it was estimated that next year the total to be carried will be 4,000,000,000. These systems include the tubes, trams, motorcoaches and other public vehicles, but do not include taxicabs and private vehicles. Nevertheless, not a single one of the transport systems is making a fair return on its investment. Power to coordinate the traffic into a combination of all transport systems in London has been given by Parliament to the committee that was formed to regulate traffic, and a common fund and common management are to be set up in which all classes of transport undertakings within a radius of 25 miles from the center of the capital are to be participants.

Mr. Gaunt was very commendatory of the automobile traffic regulations in American cities, but observed that an exasperating thing in Chicago is the lack of signs bearing street names. He suggested that if the municipality would spend a little money to fix the streets in the Loop district so that the wheels would not be wrenched off an automobile, and would put up a few street signs and provide adequate buildings and seats for all the school children, perhaps the city would not have 8,000,000 letters and 8,000,000 strangers going wrong in Chicago each year.

Asking but Not Receiving

By way of a humorous commentary on the American prosperity mentioned by the speaker from England, Chairman Powell related the story of two negroes, one of whom asked the other if his wife was asking him for money all the time.

"Yes," said Jim, "she wants 50 cents today and $1 tomorrow and 50 cents a few days ago."

"What does she do with all that money?"

"I don't know," Jim replied, "I haven't given it to her yet."

The paper on Transportation, by George W. Dixon, of the Arthur Dixon Transportation Co., that was scheduled in the program to be presented at the banquet, had been read at the afternoon session of the meeting, as Mr. Dixon had to excuse himself owing to a death in his family and the serious illness of another member of the family. The Chairman expressed his sympathy for the author, who had asked him to convey his regret to the assemblage for being unable to attend.

After narrating some of his experiences in going to see one of the early attempts of the Wright brothers to fly but which flight was not made because of a 10-m.p.h. wind, and a flight made in St. Louis in 1910 or 1911 by the pilot Hoxey, carrying Theodore Roosevelt as a passenger, Toastmaster Powell called for an address on air transport by L. D. Seymour, chief engineer of the National Air Transport, Inc. This feature, which proved most interesting and acceptable, was a late addition to the program.

He had learned only in the afternoon, said Mr. Seymour, that he was going to have to earn his dinner. Instead of following the usual procedure of speakers at banquets by pleading embarrassment because of lack of time for preparation, which no one at the banquet that night had done, he said he was reminded of the yarn about a young man who invested $2 for his first airplane ride. After getting aboard and when the plane had risen into the air after some com-

motion, it went into a spin and began doing a lot of acrobatic stunts, much to the consternation of the passenger. When he could restrain himself no longer, he tapped the pilot on the shoulder and said:

"I say, won't you take it a bit easier; this is my first ride."

He did not feel any better when the pilot turned around and replied:

"Well, brother, I'm in the same fix."

Air Transport Here Not Bottle Fed

Becoming serious, Mr. Seymour said that men in the air-transport business appreciate the sympathetic attitude of those who are interested in the development of all means of transportation. They do not believe that air transport has come upon the stage to displace any other means of transportation but rather that it is to be complementary to the railroads and to highway transportation. They hope that it can cooperate and become a representative part of the system that others assembled at the banquet had done so much to promote and develop.

No statement could be more inaccurate, he said, than that air transport in this Country is sadly behind that in Europe. The Wright brothers gave the world the first successful airplane in 1903, and to this Country has returned, in the last 2 or 3 years, the opportunity to prove that the airplane is a real commercial vehicle. Abroad the network of airlines is supported by subsidies because of the realization of the military value of airplanes and air transport, but in America we have the feeling that a business that learns from infancy to stand on its own feet is more likely to have lasting success than an industry that is brought to manhood on the bottle.

Fifteen air-transport companies now exist in the United States, asserted Mr. Seymour. These operate airplanes daily from the Atlantic to the Pacific and from the Great Lakes to the Gulf and conduct operations on many small feeder lines. In all, perhaps 10,000 miles of air routes are regularly flown in this Country. The company with which he is associated flies about 5000 miles every 24 hr., and there is no hour of day or night when one of its airplanes is not in the air. Although the magnitude of operations does not compare with that of the railroads or the motor-truck and motorcoach, the experimental work so far has shown great possibilities.

Experiments Made in Passenger Carrying

Although engaged chiefly in the carriage of mail for the Government and express matter for the American Railway Express Co., his company made an experiment in passenger carrying last September. In the 25 days of the experiment 150 passengers were carried, which works out at a full load of three passengers for each ship daily over part of the route from Chicago to Dallas, Tex. This indicates that a place exists almost immediately for passenger transport if it can be rendered at a reasonable cost. The experiment of carrying passengers together with cargo was a profitable venture, as thus the passengers could be carried for considerably less cost than they could be carried alone. The railroads need not be alarmed, said Mr. Seymour, as it is not yet certain

The Toastmaster and Speakers at the Transportation Banquet

T. C. Powell (Top), President of the Chicago & Eastern Illinois Railway Co., Who Presided at the Banquet; Brigadier-Gen. F. H. Pope, U. S. A. (Lower Center), Who Discussed the Relation of Commercial to Army Transportation; W. H. Gaunt (Left) of J. Lyons & Co., Ltd., of London, Who Also Spoke; and President J. H. Hunt (Right), Who Introduced the Toastmaster

that aircraft have been developed to the point where it will be profitable to transport passengers without other cargo. It is not known that enough people are willing to pay the cost of such transport, although the trend of development indicates clearly that in the future passenger carriage in the air on regularly organized routes will be possible.

So far as safety is concerned, the records of the National Air Transport show, asserted Mr. Seymour, that since May 12, 1926, a period of 1½ years, in day and night operation 7 days a week, the airplanes have flown nearly 2,000,000 miles and no person has been injured, no cargoes have been lost and the expense for crashes has been very light.

Despite the fact that a few attempts that have been made to adapt transport facilities in the air and on the rails to a single end have not been altogether successful, the speaker said he feels that at some future time the airplane can and will operate, not only in conjunction with the railroads, but also with motorcoaches and automobiles, to the great benefit of all.

Army Transport System and Requirements

About 2 weeks previously, said Toastmaster Powell, he saw in Baltimore a reproduction of the pony express and as Mr. Seymour was speaking he was reminded of this by contrast with the Air Mail. He cited as an example of the specific and expeditious benefit of the Air Mail the rescue from a dilemma of an official of his company, who, in the hurry of departure to attend an important conference in New York City the next day, took the train clad in the vest and trousers of a new suit but wearing an old wrinkled coat. He telegraphed en route to his wife to send the new coat to him by Air Mail, and the following morning, when he arrived in New York City, the coat was there waiting for him.

The last and, as Toastmaster Powell said without intending any disrespect of the others, the best speaker on the program, was Brigadier-Gen. Francis H. Pope, U. S. A., of the Quartermaster Corps, who then presented an address on the Relation of Commercial to Army Transportation, in which he gave a description of the Army methods and plans for the future.

In his address, Brigadier-General Pope stated that his desire was to bring out the place in the military field occupied by motor transport, the requirements of the Army in motor-transport equipment in a National emergency of the future, the method by which the Army proposes to meet its responsibilities therein, and to set forth the lessons that commercial transport can draw from the military experience.

He reviewed the intensive use of automotive transport during the World War and the organization erected for its operation. He also spoke of transport during the war in the National territory away from the theater of operations and in which the handling of motor transport differs in no way from commercial operation. He said that it has been estimated that approximately 50 per cent of the terrain in the normal field of military operations will have fairly hard surface roads, 35 per cent will have passable roads, and 15 per cent will entail cross-country work. There must be a type of motor-vehicle for Army use that will conform to each of these conditions. The essential principle to follow in determining the kind of equipment is to limit as much as possible both the varieties of make and of model, as standardization is of prime importance. Close interrelation between operation and maintenance is imperative, and the Army must establish its own service system.

Transport Types Adopted by the Army

For transportation purposes, said Brigadier-General Pope, the Army has adopted automobiles of both five and seven-passenger type; rear-wheel-drive truck chassis of ¾ to 1, 1½ to 2, and 3 to 5-ton capacity; four-wheel-drive truck chassis of 1½ to 3-ton capacity; and six-wheel, four-wheel-drive truck chassis. The military problem is the procurement of medium and heavy motor-truck equipment of the types required. Essential requirements are rugged construction and extreme dependability.

The automotive and allied industrial fields have been surveyed to determine makes and models of vehicle and the productive capacities of separate plants; all of these had to be fitted into the industrial mobilization plan, which the speaker then outlined as regards the motor-transport procurement plan. He then spoke of the Army system of maintenance, the details of which had been dealt with in the paper by Lieut. W. C. Thee, which is published in this issue of The Journal.

Essential differences between the military and the industrial organizations were reviewed, with emphasis on the fact that in military operations certainty must outweigh considerations of economy. Another great point of difference between the two ways of transport lies in the application of the principle of coordination of transport facilities, and the speaker said that motor-truck and railroad men are unable to see the forest for the trees. The experience of military transport in the war conclusively proved that coordination is not only practicable, economical and efficient, but is inevitable.

RAILROAD PROBLEMS CONSIDERED

Motor Rail-Cars and Motorcoaches Meet Competition—Distillate Advocated for Fuel

In opening the Rail-Car Session Thursday morning, H. C. Crowell, assistant to the chief engineer of the Pennsylvania Railroad, who acted as chairman, commented on the spirit of cooperation shown by the Society in railroad matters. He said that Class 1 railroads, which represent more than 90 per cent of the railroad mileage and more than 97 per cent of the total railroad revenue of the Country, carried 30 per cent fewer passengers in 1926 than in 1920. At the same time, the passenger mileage has dropped 24 per cent, showing that the decrease has been in short rides rather than in through traffic. During this time there has been an increase in the amount of train service as well as in the population. The average load per car is now 14.3 passengers. Railroad men are turning to rail-cars and motorcoaches to meet the situation.

In the absence of Walter C. Sanders, of the Timken Roller Bearing Co., his paper on The Design and Operation of Self-Propelled Railroad Cars was read by his assistant, M. S. Downes. According to the paper, the railroad will develop its service with through passenger trains, supplemented by self-propelled cars to serve intermediate stations and for branch lines and by motorcoaches to reach other points.

In many cases, motorcoaches are not competitors of the railroads but are complementary to them. The next decade will see airplanes as well as motorcoaches and motor-trucks added extensively to the railroad transportation systems.

A number of cost figures were given in the paper and summarized in the statements that a self-propelled car will operate at about one-half the cost of the three-car train it replaces, and that a motorcoach will operate for about one-half to two-thirds the cost of a rail-car.

Design Now Based upon Experience

With 600 rail-cars now in service on American railroads, there is a basis of experience for the improvement of rail-car design. The tendencies are toward increasing the size and strength, more accessible arrangement of powerplants, refinements to secure more efficient operation, and simplification of control. Reliability in operation is the first necessity. At present electric drive seems to be more desirable than mechanical drive, but Mr. Sanders believes that mechanical drives that are simpler in design and lower in both original and operating costs will come soon.

Large double-powerplant cars have been developed that are capable of handling trailers weighing 200 tons or more, under favorable conditions, this capacity being sufficient for the replacement of almost any accommodation train. The use of aluminum alloys as a means of reducing weight will allow much of this work to be done with a single-powerplant car. This possibility is further increased because much of the buffing shock is eliminated.

PART OF THE EXHIBIT OF TOOLS AND EQUIPMENT

Through the Courtesy of the Chicago Jobbers of Automotive Tools and Equipment the Exhibit, Used as a Demonstration of Maintenance Processes Following Martin E. Goldman's Paper, Was Open during the 3 Days of the Transportation Meeting

Important details of construction should include provision for passenger comfort in the seating arrangement of the car and in springing. An important point to be considered in the design of both the brakes and the truck structure is the large amount of labor involved in removing an axle to correct a flat wheel.

Antifriction bearings will relieve the transmission of its overload in starting. The rail-car transmission should be more rugged in proportion to the power transmitted than is customary for motorcoaches and motor-trucks, because of the greater weight to be handled and because it is sometimes necessary to operate for a long period in intermediate gears at full-open throttle.

Oil Engines Are Wanted

Electric or hydraulic transmission is considered necessary with an oil engine but the possibility of the use of an oil engine with a direct mechanical transmission should be studied, in the opinion of Mr. Sanders. Promising results are being secured by the New York, New Haven & Hartford Railroad from a car having hydraulic transmission, and a rail-car with a steam powerplant is under development. As rail-cars are now being produced that will make savings within a few years equal to their entire first cost, there is no need for a railroad to wait for improvements in fuel economy that may be made possible by Diesel-engine development.

Rigid inspection schedules are important. Car bodies and trucks are ordinarily good for 20 years of service and it seems quite possible to design powerplants that will have equal life, with the renewal of cylinder liners and other wearing parts. In one instance a car was operated 150 miles per day, during its first 6 months of service, with only two mechanical delays of 10 min. each. It then went to the shop because of a collision. The paper said that a check of delays shows that almost all af them are caused by minor items that could be eliminated by careful maintenance.

The Fuel Situation Is Analyzed

Rail-Car Fuels was the subject of the next paper, presented by E. Wanamaker, electrical engineer of the Chicago, Rock Island & Pacific Railway Co., who recalled that well-informed experts a few years ago predicted a gasoline famine by 1927, but later discoveries of new fields has made the supply plentiful. Should the supply fail, a substitute would be developed, but we should not neglect economical use even in the present time of plenty.

Practically available fuels include gasoline, distillate and light and heavy fuel-oils. Distillate is used in a slightly modified gasoline engine, and light fuel-oil in a solid-injection Diesel engine with metering pump; heavy oil requires a low-speed Diesel engine too heavy for rail-car use, according to Mr. Wanamaker.

Distillate is left from the cracking process of producing gasoline, much as kerosene remains from straight distillation. In a suitable engine it produces power at less cost than with gasoline, it is safer to store and carry, less liable to theft, and gives smooth operation. The cost is about 4 cents per gal. less than that of gasoline, and Mr. Wanamaker expects the differential to increase as the price of gasoline rises.

Frequent changes of crankcase oil are required with distillate, and an oil-reclaiming plant saves about three-quarters of the oil without loss of lubricating value. The net saving from using distillate in place of gasoline in a 90-ton two-car train with 75-hp. engine has been found to be just over 2 cents per mile, an amount that would pay for the entire car in 10 years.

Rail-Cars Carry Express Shipments

After the reading of Mr. Wanamaker's paper, discussion was begun by a question from E. W. Weaver, of the George T. Trundle Engineering Co., who inquired how the increased size and weight of rail-cars is reconciled with the statement of the low average number of passengers carried in steam trains. Mr. Wanamaker replied that the chief reason is the express carried. Frequently a single motor rail-car is not sufficient to replace a steam train but, even if a trailer is used, the total weight is very much less than that of a locomotive and two cars.

H. F. Fritch, of the Boston & Maine Railroad, mentioned the desirability of trains that can be operated from either end. As the rail-cars of the Boston & Maine Railroad can be operated from either end, it is not necessary to turn the car, but when the powerplant is coupled next to the trailer it is difficult to pass from one car to the other. Mr. Fritch's experience with distillate is not entirely satisfactory, he said, but indicates that successful operation may be attained. On damp days there have been a number of complaints because of the odor of exhaust fumes.

Mr. Wanamaker responded that dilution of crankcase oil is much greater when distillate instead of gasoline is used for fuel. The frequent change of the oil which this necessitates keeps the engine clean and is made practicable by the oil-reclaiming practice explained in his paper. As the distillate has some lubricating value, the dilution is not dangerous.

A Successful Boiler Is Awaited

According to W. A. Burton, of the Steamotor Co. of Chicago, the boiler has been the limiting factor in the development of steam rail-cars. He recounted some of the work in developing a car, using steam pressure of 500 lb., which was not a commercial success because of oil finding its way into the boiler. Present development is taking the form of a turbine fed with steam from a generator operated upon a recently patented system wherein steam is produced without ebullition.

E. C. Wood reported that there is not much rail-car operation on the West Coast, but on one road bordering the Pacific Ocean, where a three-car steam train made only three short trips per day, the passenger traffic has been increased considerably by providing a rail-car having an observation platform at the rear, which it had not been practical to provide on a steam train. The number of trips has been increased and the cost reduced.

The question of comparative maintenance cost with distillate or gasoline fuel was brought up by K. J. Ammerman, who remarked that the oil dilution with distillate is so great as to cause excessive wear, some reports indicating an increase of 2 cents per mile in maintenance cost with distillate.

New England Experience Told

Rail-Car or Motorcoach; the Economic Field of Each, was the subject of the third paper of the morning, in which H. F. Fritch recounted some of the experiences of the Boston & Maine Railroad in "using the hair of the dog to cure its bite" by adopting the internal-combustion engine to solve the problems resulting from the inroads of the private automobile into its traffic. Only the classes of transportation usually provided by passenger trains were covered directly in the paper, in which it was stated that no general rule can be laid down for deciding whether rail-car or motorcoach service should be substituted, as each case must be decided according to conditions.

One of the first considerations is whether the railroad is needed for other than passenger traffic. If not, the motorcoach has a great advantage in using a publicly supported roadway. The highway must also be studied as to character, capacity and convenience to the communities to be served, with due weight given to the greater flexibility of route of the highway vehicles. For instance, all passenger-train traffic except express shipments is now handled by motorcoach over the 13 miles between Franklin and Bristol, N. H., taking passengers and mail to the center of Bristol instead of leaving them at the foot of a long hill, and taking the children directly to their school in Franklin.

Between Springfield and Northampton, Mass., five round trips per day with a 73-ft. rail-car give suburban service over a 17-mile route where at least part of the work might be done by motorcoaches but for a competing trolley company that interferes with procuring licenses. Some of the rail

service between Northampton and Greenfield, Mass., has been replaced by a motorcoach line. Rail-car units give all the service over the 96 miles between Worcester, Mass., and Concord, N. H., except for one main-line connection that is made by a motorcoach. The service between several other towns and cities was described in the paper, with reasons for the selection of the equipment chosen.

The Requirements of Labor Enter

The labor expense for each run is considered, in view of the minimum wages and limitation of hours and mileage for the rail-car crew. The difference is not great if the capacity of a rail unit is needed, but counts in favor of the motorcoach where traffic is lighter. Volume of traffic often decides which unit shall be used. This railroad now has 24 rail-cars in service and its allied transportation company has 72 motorcoaches, 22 of which are in substitution for rail service. Some of the runs made by the rail-cars are to give increased frequency of service, which seems to be worthwhile in attracting more business.

Neither the motor rail-car nor the motorcoach is believed by Mr. Fritch to have reached the high degree of development of the motor-car, but good serviceable units of each kind are being produced. They help to keep the railroads on a sound operating basis while they furnish organized transportation to some communities that otherwise would be without it and more frequent service to others than would be possible with more expensive units.

Chairman and Speakers at the Rail-Car and Motorcoach Session

H. C. Crowell (Top), Who Presided at the Rail-Car and Motorcoach Session; K. J. Ammerman (Lower Right), Who Discussed Motorcoach Design; H. F. Fritch (Center), Who Discussed the Economic Fields of the Rail-Car and Motorcoach; E. Wanamaker (Upper Right), Who Discussed Rail-Car Fuels; M. S. Downes (Lower Left), Who Presented W. C. Sanders' Paper on Rail-Car Design and Operation; and G. F. Dell (Upper Left)

In response to a question, Mr. Fritch said that he did not know the average number of passengers per coach carried by the Boston & Maine Railroad, but it is seldom practicable to use a rail-car without a trailer to replace a train consisting of two or three cars and including a passenger car, a smoker, and provision for baggage and probably for mail and express. In some instances, certain trips can be made without a trailer.

Seating Arrangements Are Studied

The smallest motorcoaches used by this company have seats for 21 passengers but most of them are for 29 passengers. A number of motorcoaches of the 29-passenger size were made with single seats on one side of the aisle, providing for only 20 passengers. Concluding that this arrangement did not pay, these motorcoaches have been changed to provide 29 seats. Most of the rail-cars used on this road have two seats on one side of the aisle and three seats on the other, in each row. Mr. Fritch believes that on some lines this arrangement should be changed to provide more comfort by providing seats for only four passengers in each row.

Asked if any attempt had been made to supplement the passenger service by the use of motor-trucks, Mr. Fritch said that on one line, where the company is seeking permission to substitute motorcoach service for train service, it will use a motor-truck to handle the Sunday newspapers. They are not now using motor-trucks at all in conjunction with motorcoach routes but are using them in the handling of local freight.

Comparative figures by D. C. Hershberger, of the Westinghouse Electric & Mfg. Co., gave $1.58 as the cost per mile for a steam train, 72 cents per mile for a gas-electric rail-car and 28.9 cents per mile for a motorcoach. With half the seats full, this would make the cost per passenger-mile 16 cents for the steam train, 1 cent for the rail-car and 1.9 cents for the motorcoach.

MOTORCOACH STATUS DISCUSSED

Design, Present and Future Legislation and West-Coast Operation Treated

Because of the crowded program of the morning session, part of the afternoon session on Thursday, Oct. 27, was taken up in finishing the discussion of the papers presented in the forenoon. However, enough time remained for the presentation of papers on the motorcoach, the phases considered being those suggested in the foregoing title.

Motorcoach Design

The paper on design was by K. J. Ammerman, of the American Car & Foundry Motors Co. The author said in part that success in building motorcoaches depends on ability to provide riders with safe comfortable rides in motorcoaches that can be operated at a profit. The development of motorcoach construction parallels that of railroad coaches in many respects and is passing through the same course of evolution. But the demands on the motorcoach are more severe, for, in addition to higher maximum speeds, the vehicles must have greater accelerating and decelerating ability. This imposes greater strains on the chassis and the body than do high maximum speeds. Simplicity is the predominating characteristic of good design and, when attained, is accompanied by low cost of maintenance.

The topics discussed by the author included the effects of excessive overhang, the importance of proper weight-distribution, the sales value of the comfort of passengers, the baggage problem, the value of sturdy appearance in enhancing the rider's confidence, the economy of standard body-building and the costs imposed by deviations from standardized design. Methods of construction were illustrated and views of several leading types of motorcoach were shown.

In the absence of the author, F. C. Horner read the paper by Robert H. Newcomb, formerly assistant to the vice-president of the New York, New Haven & Hartford Railroad, outlining present conditions as affected by motorcoach legislation. Commenting on the great variety of forms of regulatory legislation, the author stated that 48 separate and distinct jurisdictions have nearly 48 separate and distinct sets of regulations. If there are no statutes in a certain jurisdiction, the courts can always be called upon to interpret the law covering conditions in a State that has no regulatory statute. It is only when the highway vehicle crosses a State line that the confusion of jurisdiction and the absence of Congressional legislation steps in to emphasize the necessity for coordinated law.

The varying phases of the problem of carrying passengers are sufficiently vague to provide ample material for discussion, according to Mr. Newcomb. When one stops to investigate the carriage of freight on the highway, complications pile up at such a rapid rate that he is brave indeed who attempts to unravel the snarl. This much is certain, whether any given operation makes the operator a common carrier is a matter of fact and not of law, and no operator can be declared a common carrier on the highway, whether of passengers or freight, and have that declaration valid. It is the transaction itself and not the movement of any vehicle which constitutes common-carrier service within the meaning of the law. It is well always in discussions of this sort to keep that distinction in mind, and, to make the distinction even more definite, let it be said that it is futile for a legislative body to declare "all persons engaged in the transportation of persons or property for hire" by motor-vehicle to be common carriers.

Future Motorcoach Legislation

In predicting what the future regulatory legislation may be, in reference to the motorcoach, A. M. Hill, president of the Blue and Gray Lines, of Charleston, W. Va., first outlined past events that have led up to the present situation. Mr. Hill's paper, which was read by C. G. Moore, in the author's absence, stated that the benefits of proper regulation are many, embodying primarily protection of the public as to the character of service, responsibility and reliability of the operator and the placing of interstate motorcoach operations on the same high plane of public service which has followed sane and wise regulation of lines wholly within a number of our States. The paper then described the bill upon which a committee of motorcoach operators has been working for more than 2 years and which is to be presented to Congress. Upon the formation of the Motorcoach Division of the American Automobile Association, this committee's work was taken over by the latter organization. The committee has worked in closest cooperation with the National Association of Public Utility Commissioners and, in addition, has had numerous conferences with railroad and electric-railway representatives.

In conclusion, Mr. Hill asserted that sane and far-seeing operators have realized that the best methods of combating antagonistic legislation is through the State associations and the further drawing together of all the operators of the Country in a strong National association. Such an organization exists in the Motorcoach Division of the American Automobile Association, which purposes to establish a legal research department whereby information and help can be given in combating all adverse and antagonistic legislation and assistance can be lent in cases throughout the Country in which a principle affecting the whole industry is involved. Unquestionably, the motorcoach has a great and important place in the transportation scheme of America and appeals very strongly to the great mass of our population. It is therefore important and necessary, said the author, that operators all over the Country work in cooperation in their own States and with the National association. This certainly will result in the passing of legislation which will tend to encourage, nourish and stabilize the growth of this industry which, while young, is now covering more than 270,000 route-miles.

Regarding motor-vehicle operation in the Far West, E. C. Wood, of San Francisco, said that the natural conditions in the coastal area and the linkage of prominent cities with their suburban areas, together with the distribution of the

population and the moderate average temperature, make this an ideal region for motorcoach operation. The rate of speed allowed in highway travel makes it possible for the prominent centers to be reached within the daylight hours and, with the many tributary and arterial systems provided by the motorcoach, the public is given a service that places the contact factor of business in an efficient schedule and in a central location. The future growth and development of the suburban and outlying districts there are being aided greatly by the efficient service given the public by the motorcoach.

The motorcoach maintenance problem has resulted in the development of systems of higher efficiency in inspection and in mechanical repairs, and a higher efficiency of the initial equipment, than has any other branch of the operating field. The inspections include the number of hours in daily operation of the unit and the period of time allowable for the inspection on reaching the destination. The mechanical driver's seat and the pedals and levers he must operate presents difficulties in that the driver must modify his movements as compared with those in other vehicles with which he already is familiar. By way of illustration, he mentioned the hand brake; on some types of vehicles this lever is pushed and on some it is pulled. Some hand brakes can be operated easily and are accessible, but in other cases the driver must reach for them and they are hard to operate. In some cases, the hand brake is located at the left of the driver and in other cases it is at the right. Details of this nature have a tendency to make operation difficult.

Mr. Debbink then enumerated other conditions which may have an effect on efficient operation. Among these are the mounting of the driver's seat in relation to the steering-wheel, differences in pedal pressure required, the provision of sufficient leg room for passengers so that they can be comfortable, the provision of gasoline tanks of sufficient capacity to

AMONG THOSE WHO TOOK AN ACTIVE PART IN THE DISCUSSION

From Left to Right, A. J. Scaife, of the White Co.; James Monroe, of the Trailmobile Co.; Harry Moock, of the Automotive Equipment Association; H. C. Marble of the White Co.; and A. W. Einstein, of the National Retail Dealers Association. Edward Wotton (Top), of the Chicago Motor Coach Co., a Member of the Transportation Meeting Committee, Was in Charge of the Inspection Trips

partments are very efficiently tooled and, as the unit-replacement system is generally used, the departments have many efficient features and facilities. The auditing systems comprise recognized fundamentals. Other phases of the maintenance problems, such as tire replacements, fueling, reconditioning of equipment and the like, are the products of well-developed systems, and the efficiency methods of these systems are localized to meet the particular condition. In Mr. Wood's opinion, the future development of the motorcoach has many phases yet to improve, and the speaker made general comment on the likely changes in motorcoach design.

OTHER FEATURES OF DESIGN AND OPERATION

Following the presentation of the papers, H. L. Debbink, of the Milwaukee Electric Railway & Light Co., outlined some of this company's practices. The company has a well standardized course of instruction for motorcoach drivers and teaches them standard methods of operation. In the case of new equipment in which differences of the controlling mechanisms exist, special instruction is given the drivers before they are allowed to operate that particular type of vehicle in regular service. The speaker said that each new type of vehicle that has different relations between the operate the vehicle over its specified route, the mounting of these tanks as a feature of the original design rather than as an afterthought, and the provision of adequate and suitable luggage-carriers.

C. B. Norris, of the Haskelite Mfg. Corporation, talked on the subject of proper distribution of the weight of motorcoaches on the front and the rear axles and drew diagrams to illustrate his remarks. He also described methods that can be used to determine the proportions of load carried by the front and rear axles of motorcoaches that are in service. Asked by A. J. Scaife, of the White Motor Co., what the desirable passenger-carrying capacity is for a single-deck motorcoach, F. A. Whitten, of the American Car & Foundry Motors Co., stated that a 40-passenger capacity is best from the operator's viewpoint.

FUTURE TRENDS OF OPERATION

Brigadier-Gen. Francis H. Pope, chief of the transportation service of the Quartermaster Corps, U. S. A., said in part that, although he can understand the motives of people who now travel by motor-vehicle for long distances, as across the continent, in preference to traveling on luxurious railroad trains, he believes long-distance travel in motor-vehicles

to be a passing phase. This, in his opinion, is due to the fact that long-distance highway-operation is not economical when compared with long-distance railroad-operation. The chief public appeal of the railroad is its reliability for mass transportation over long distances, and the railroads can, in his opinion, do this more economically than it can be done on the highways. He thinks that railroad operation and highway operation therefore occupy two different fields of economic service to the public.

In reply, Chairman Horner mentioned that during 1926 from two to five motorcoaches in summer and from one to two motorcoaches in winter were run over the motorcoach line between Los Angeles and Denver, and that, as a result of a check-up made about 18 months ago, it was discovered that these vehicles carried 134 passengers in one day from Denver to Kansas City in an elapsed time of 8 hr., and that all the railroads between these cities carried only 22 passengers. He mentioned the long-distance motorcoach lines between Chicago and the Pacific Coast, which include intermediate cities, and said that the vehicles are sufficiently well patronized to make the undertaking profitable. He asserted also that the motorcoaches running between San Francisco and Portland, Ore., a distance of about 760 miles, travel over a mountain range and make the trip in 31 hr. regularly, while the average train time in winter between these cities is something like 29 hr.

1927 Transportation Meeting Registration

AMMERMAN, K. J., executive, American Car & Foundry Motors Co.
AMRINE, L. H., special represenative, Dallas Brass & Copper Co.
ANDERSON, E. S., superintendent of transportation, Great Atlantic & Pacific Tea Co.
ANDERSON, GEORGE P., director of sales engineering, Dodge Bros., Inc.
ANDERSON, N. G., chief engineer of the Springfield Works, International Harvester Co.
BABCOCK, C. W., Midland Utilities Co.
BAKER, M. WARREN, field editor, Chilton-Class Journal Co.
BALDWIN, TIMOTHY J., transportation superintendent, Purity Bakeries Corporation
BALLENTINE, R. W., assistant manager of automotive sales, Timken Roller Bearing Co.
BARBER, H. E., president, Egyptian Transportation System
BARR, T. A., supervisor of freight agents, Chicago, South Shore & South Bend Railroad
BARTHOLOMEW, J. R., manager of manufacturers' sales, Westinghouse Air Brake Co.
BARTLETT, P. H., sales department, Eaton Bumper & Springs Service Co.
BAUMGARTEN, A. W., chief engineer, Chicago & Joliet Electric Railway Co.
BEATTIE, J. B., branch district manager, Lapier Trailer Corporation
BEATTY, W. H., Jr., Westinghouse Air Brake Co.
BECK, C. H., general sales manager, Westinghouse Air Brake Co.
BECK, MILTON, chief engineer, Stanley Steamer, Inc.
BECKER, WALTER C., superintendent of motorcoach service, Chicago Surface Lines
BENSLEY, JOHN R., vice-president and general sales manager, Mercury Mfg. Co.
BISESI, J. L., material inspector, Chicago, Rock Island & Pacific Railway Co.
BISSETT, CARL F., engineer, Anderson Engine Co.
BLAKESLEE, C. J., works manager, Walker Vehicle Co.
BLANCHARD, D., operation and maintenance editor, Chilton-Class Journal Co.
BLOSS, ERNEST K., assistant electrical engineer, Boston & Maine Railroad
BLOTT, E. M., salesman, Davis Welding & Mfg. Co.
BOWER, L. L., installation engineer, Waukesha Motor Co.
BOWYER, AMBROSE, publisher, *Motor Service Magazine*
BRACKETT, F. G., manager of survey department, Yellow Truck & Coach Mfg. Co.
BRITAIN, GLENN H., car equipment engineer, Chicago, North Shore & Milwaukee Railroad Co.
BROWN, T., national account sales, Miller Rubber Co.
BRYAN, HARRY F., engineer in charge of carbureter division, International Harvester Co.
BRYAN, W. J., sales manager, Heintz Mfg. Co.
BUCHANAN, F. C., sales manager, Columbia Steel Tanks Co.
BURDETTE, C. N., Hyatt Roller Bearing Co.
BURGER, L. F., chief engineer, International Harvester Co.
BURKE, J. H., traffic manager, Chicago Tunnel Co.
BURKHOLDER, F. O., sales manager, Ahlberg Bearing Co.
BURNETT, R. S., standards manager, Society of Automotive Engineers, Inc.
BURTON, W. D., chief engineer, Steamotor Co.
CALLAHAN, G. J., national account sales, Miller Rubber Co.
CASTOR, S. R., assistant chief engineer, H. H. Franklin Mfg. Co.
CATE, GARTH W., manager, Flexo Motive Corporation
CERVENKE, JOHN A., superintendent of equipment, Edward Hines Lumber Co.
CHARTER, J. A., Charter Motors
CHUCAN, J., chief engineer, Mercury Mfg. Co.
CLAPP, E. W., traffic manager, Southern Pacific Lines
CLARKSON, C. F., general manager, Society of Automotive Engineers, Inc.
CLEVELAND, B. C., metallurgist, Bell & Gossett Co.
CLINE, STANLEY C., service manager, Gabriel Snubber Sales & Service Co.
CLOHISY, WARREN A., manager, Overman Cushion Tire Co.
COLEMAN, H. B., secretary, assistant treasurer and sales manager, Hoopes Bro. & Darlington, Inc.
COLLINS, F. A., sales department, White Motor Co.
CONSTANTIN, M., division auditor, Mack Trucks, Inc.
COSTELLO, J. W., superintendent, Chicago Tunnel Co.
COWIE, GEORGE A., accountant, Armand & Co.
CRASPER, M. T., city passenger agent, New York Central Railroad
CROSBY, G. L., vice-president in charge of sales, Roller-Smith Co.
CROWELL, H. C., assistant to chief engineer, Pennsylvania Railroad
CURTS, ROBERT M., research division, New Jersey Zinc Co.
DAKIN, HENRY, superintendent of automotive equipment, Michigan Bell Telephone Co.
DAMMANN, H. W., secretary, Bear Mfg. Co.
DANBER, EDWARD, office manager, Great Atlantic & Pacific Tea Co.
DANNER, W. L., sales engineer, Simplex Piston Ring Co.
DOYING, GEORGE E., counselor, Pierce-Arrow Bus Line Co.
DEBBINK, HENRY L., superintendent of gasoline-driven vehicles, Milwaukee Electric Railway & Light Co.
DELL, G. F., superintendent of railway traffic and engineer, Scott Bros., Inc.
DE MORE, L. A., salesman, Autocar Sales & Service Co.
DERBYSHIRE, G. J., general superintendent, Chesapeake & Ohio Railroad Co.
DICK, ROBERT I., chief engineer, The Buhl Co.
DOBLER, A. H., Elwell Parker Co.
DORRIS, GEORGE P., Dorris Motor Car Co.
DOWNES, M. S., assistant to general manager of the railway division, Timken Roller Bearing Co.
DRAKE, CHARLES L., automotive division of the sales department, SKF Industries
DUNLAP, JAMES E., general service manager, Walker Vehicle Co.
DYSTERUD, OLAF J., superintendent, Nelson-Le-Moon Truck Co.
EDMUNDS, W. H., vice-president and general manager, Denver Interurban Motor Co.
EINSTEIN, A. W., manager, National Retail Delivery Association
EINSTEIN, ROBERT, production engineer, Cadillac Motor Car Co.
ELLINGWOOD, J. R., Chicago branch sales manager, Federal Motor Truck Co.
ERICKSON, E. D., manager of the commercial car division, Overland Motor Co.
ERLACH, P. A., Midland Utilities Co.
FARR, ERNEST, Miller Rubber Co.
FAULKNER, FRED L., automotive engineer, Armour & Co.
FENLEY, W. H., Western manager, Kerite Insulated Wire & Cable Co.
FERGUSON, FRED G., vice-president, Simplex Piston Ring Co.
FERRANDON, A. H., director of motorcoach division, Dodge Bros., Inc.
FILES, H., superintendent of garages, Shore Line Motorcoach Co.
FINCH, N. A., Jr., railroad department, The Trailmobile Co.
FISKE, F. H., chief motor inspector, The Texas Co.
FOSS, MARION H., department manager, Wilson & Co.
FRAMHEIN, H. J., chief engineer, Walker Vehicle Co.
FRASER, EDWIN J., service manager, General Motor Truck Co.
FRITCH, H. F., passenger traffic manager, Boston & Maine Railroad
FROEBEL, G. H., assistant director of heavy traction, Westinghouse Electric & Mfg. Co.
FROST, A. H., central manager of the manufacturers' service division, Vacuum Oil Co.
GAIDZIK, GEORGE, assistant to president, Biflex Corporation
GALVIN, J., Pennoyer Merchants Transfer Co.
GANZERT, A. E., electrical supervisor, Chicago, Rock Island & Pacific Railway Co.

GARDINER, ARTHUR W., research engineer, General Motors Corporation Research Laboratories
GAUNT, W. H., J. Lyons & Co., Ltd., London, England
GENUNG, G., transportation supervisor, Public Service Co. of Northern Illinois
GILE, F. B., Arthur Dixon Transfer Co.
GLYNN, F. K., engineer, American Telephone & Telegraph Co.
GOLDMAN, MARTIN E., manager of the shop equipment division, Automotive Equipment Association
GOODRICH, F. H., sales engineer, C. G. Spring & Bumper Co.
GRAVES, A. W., student, Chicago
GRAY, J. K., general superintendent, South Shore Line
GRIFFIN, J. C., sales department, Mack Trucks, Inc.
GRIFFIN, N. M., vice-president, Mack Trucks, Inc.
GUNLOGSON, G. B., vice-president, Western Advertising Agency.
GUNDLACH, L. J., treasurer, Chicago Tunnel Transport Co.
HADLEY, GEORGE W., student, Iowa State College
HAGEN, G. E., superintendent, Southwestern Michigan Motor Coach Co.
HAIGHT, C. W., manager, Greater Service Express
HANRAHAN, M. T., superintendent of vehicle service, American Railway Express Co.
HARDY, H. H., secretary, Michigan Motor Bus Association
HAUSSER, CURT, chief motor inspector, Waukesha Motor Co.
HARRISON, ROBERT D., automotive engineer, General Electric Co.
HEINLY, D. G., representative, McGraw-Hill Publishing Co.
HELD, W. M., engineer, New Departure Mfg. Co.
HERMAN, FRANK P., sales manager, Lovejoy Mfg. Co.
HERNDON, D. E., electrical superintendent, Chicago, Rock Island & Pacific Railway Co.
HERRINGTON, A. W., consulting engineer, City of Washington
HERRMANN, K. L., consulting engineer, Studebaker Corporation of America
HERSHBERGER, DAVID C., assistant engineer, gasoline-electric traction, Westinghouse Electric & Mfg. Co.
HEYWOOD, C. E., manager of the meetings and sections department, Society of Automotive Engineers, Inc.
HORINE, M. C., sales promotion manager, International Motor Co.
HORNER, F. C., assistant to the vice-president, General Motors Corporation
HOUGHTON, E. C., superintendent of transportation, Shore Line Motor Coach Co.
HUFF, LEO, general manager of motor equipment, The Pure Oil Co.
HUNT, J. H., Chevrolet Motor Co.
HYATT, J., assistant to the vice-president, Chicago, North Shore & Milwaukee Railroad
IRWIN, B. F., engineer, Western Electric Co.
ISBESTER, G. C., Elwell-Parker Electric Co.
JACKLIN, H. M., associate professor of automotive engineering, Purdue University
JAHN, E. W., superintendent of transportation, Consolidated Gas & Electric Co.
JOHNSON, A. M., special representative, Hutto Engineering Co.
JOHNSON, C. A., railway division, Hyatt Roller Bearing Co.
JOHNSON, H. E., cost clerk, Public Service Co. of Northern Illinois
JOHNSON, S., JR., assistant district engineer, Westinghouse Air Brake Co.
JOHNSON, WILLIAM T., E. D. Kimball Co.
JUPP, WILLIAM B., rail-car design engineer, Mack Trucks, Inc.
KANAAR, R. P., special representative, Firestone Tire & Rubber Co.
KANE, GEORGE E., passenger representative, Boston & Maine Railroad
KANTERS, L. M., engineering department, Waukesha Motor Co.
KEARNEY, WILLIAM G., manager of testing, tire division, B. F. Goodrich Co.
KEITH, R. R., Chicago
KENNER, E. R., special representative, B. F. Goodrich Rubber Co.
KERSHIN, J. K., Kershin Motor Express Co.
KIRBY, H. E., Chicago
KIZER, H. W., superintendent of motor equipment, The Texas Co.
KLINK, W. L., advertising, Pennsylvania Railroad
KNEPPRETH, H. F., business manager, Heit Co.
KOEHLER, R. C., service engineer, Yellow Truck & Coach Mfg. Co.
KOHL, J. J., general manager, The International Tool Co.
LAMKIN, W. S., garage superintendent, Shore Line Motor Coach Co.
LAURANCE, R. J., superintendent, Cudahy Packing Co.
LEVITT, D. L., salesman, Paige Co.
LEWIS, C. D., salesman, Watkins Rebabbitting Service
LITTLE, M. D., superintendent, Shore Line Motor Coach Co.
LOOMIS, EDWARD F., manager of truck department, National Automobile Chamber of Commerce
LORENZ, E. R., service tool division, Nash Motors Co.
LOWE, E. F., general manager, K. P. Products Co.
LOZON, R. J., salesman, railway division, International Harvester Co.
LYNCH, R. J., engineer, New Departure Mfg. Co.
MCAULIFFE, L. T., sales manager, B-K Brake Corporation
MCCURDIE, J. F., salesman, Ferodo & Asbestos, Inc.
MCCUTCHEON, W. A., superintendent of automobile department, West Penn Power Co.
MCDONALD, J. E., assistant sales engineer, Overman Cushion Tire Co.
MCGREW, COL. M. L., United States Army
MCINDOO, O. W., plant supervisor, Illinois Bell Telephone Co.
MCMANUS, R. J., dispatcher of tractors, American Railway Express Co.
MCWILLIAMS, GEORGE L., assistant secretary, International Association of Milk Dealers
MACKEY, F. J., Fairbanks, Morse & Co.
MACLEAN, G. A., salesman, Yellow Truck & Coach Mfg. Co.
MANDEL, SIG., vice-president, chief engineer, Husky Wrench Co.
MANLEY, TRELL, assistant sales manager, Gabriel Snubber Sales & Service Co.
MANTELL, JOHN J., New York City
MANVILLE, K. R., engineer, International Motor Co.
MARBLE, H. C., vice-president, The White Co.
MARTIN, C. W., garage superintendent, Shore Line Motor Coach Co.
MARTY, M. J., engineer, Chicago Mfg. Co.
MEISSNER, L. F., JR., salesman, Ward Motor Vehicle Co.
MERRIAM, J. R., Waukesha Motor Co.
MICHELET, CHARLES J., industrial engineer, Peoples Gas Light & Coke Co.
MILLIKIN, F. A., transportation department, Public Service Co. of Northern Illinois
MIZER, JOSEPH J., chief engineer, Walker Mfg. Co.
MOCK, F. C., research engineer, Stromberg Motor Devices Co.
MOELLER, H. O., division service manager, Mack Trucks, Inc.
MONROE, JAMES, president, The Trailmobile Co.
MOOCK, HARRY, Automotive Equipment Association
MOORE, CHESTER G., United Motor Coach Co.
MOORE, G. T., vice-president, Wisconsin Parts Co.
MOORE, JAMES E., assistant to the president, Climax Engineering Co.
MORCOM, J. H., superintendent of transportation, Shore Line Motor Coach Co.
MORRISON, R. L., representative, Westinghouse Air Brake Co.
MORRISON, T. A., superintendent of freight service, Chicago, South Shore & South Bend Railroad
MOULDING, J. W., Jr., superintendent of equipment, Thomas Moulding Brick Co.
MUNN, M. D., repair service engineer, White Motor Co.
MURPHY, E. L., Jr., Murphy Transportation & Storage Co.
MYERS, C. T., managing director, Chassis Lubricating Co.
NAPHESS, PETER L., vice-president, American Freight Service, Inc.
NATHAN, WALTER S., service department, Nash Motors Co.
NELSON, NELSON B., sales engineer, New Departure Mfg. Co.
NORRIS, CHARLES B., mechanical engineer, Haskelite Mfg. Corporation.
NOYES, E. M., Chicago representative, Wolverine Trailer Corporation.
OATES, J. GRAHAM, dredge engineer, Canacules Zinc Co.
OGDEN, G. L., in charge of emergency hauling, Public Service Co. of Northern Illinois.
OHL, C. A., representative, Westinghouse Air Brake Co.
O'NEILL, J. E., assistant to vice-president, American Railway Express Co.
OSBORNE, W. L., Osborne Process, Inc.
PEACOCK, ALFRED B., special representative, B. F. Goodrich Co.
PERKINS, DOW W., transport engineer, Mack-International Motor Truck Corporation.
PERSHALL, S. F., superintendent of bureau organization, American Railway Express Co.
PFEIFFER, BENJAMIN S., consulting engineer, Chicago.
PFEIFFER, R. S., engineer, development department, Western Electric Co.
PIERCE, HENRY A., manager Chicago office, Brown-Lipe Gear Co.
PIETSCH, FRANK H., manager national accounts, Mack-International Motor Truck Corporation.
PLIMPTON, R. E., associate editor, *Bus Transportation.*
POPE, BRIGADIER-GEN. F. H., U. S. A., chief of transportation, Quartermaster Corps.
PORTUGAL, H. R., district manager, Thermoid Rubber Co.
PRINCE, T. C., branch manager, Fruehauf Trailer Co.
REILLY, H. K., general superintendent, Davis Welding & Mfg. Co.
RISTINE, JOHN D., sales, The Arco Co.
ROBERTSON, WALTER E., president, Robertson Resilient Wheel Corporation.
ROBIE, THEODORE M., sales engineer, Fairbanks, Morse & Co.
ROCHE, PAUL L., Western manager, *Automobile Topics.*
RICKERT, HAROLD, buyer, Pure Oil Co.
RUSSELL, THOMAS A., Hyatt division, General Motors Corporation
RUTHERFORD, F. H., superintendent of terminals, Chicago & Eastern Illinois Railway Co.
SAMPSON, F. W., engineering department, Continental Motors Corporation
SANDERS, R., salesman, A C Spark Plug Co.
SANGER, A. L., manager, Cartage Exchange of Chicago
SCAIFE, A. J., engineer, The White Co.
SCARR, F. J., construction engineer, proprietor, Scarr Transportation Service
SCARRATT, A. W., chief engineer, motor-trucks and motorcoaches, International Harvester Co.

SCHANK, HARRY E., assistant engineer, McCord Radiator & Mfg. Co.

SCHNITZ, H. A., chief inspector, Chicago, Rock Island & Pacific Railway Co.

SCHULZ, A. C., chief engineer, B-K. Corporation

SEARS, WILLIAM A., automobile instructor, Lane Technical High School

SEELY, G. T., vice-president, Chicago Motor Coach Co.

SEWARD, J. M., Scarr Transportation Service

SHAW, ALEXANDER, J., supervisor of automobile repairs, Public Service Co. of Northern Illinois

SHELLEY, J. G., special representative, Dodge Bros., Inc.

SHERWOOD, A., salesman, Columbian Steel Tank Co.

SHIELDS, J. W., sales engineer, Firestone Tire & Rubber Co.

SHOEMAKER, J. H., sales manager, Gabriel Snubber Sales & Service Co.

SICK, GEORGE E., inspector of motor service, Pennsylvania Railroad

SIEVERS, RAY, Highland Auto Repairs Co.

SILVA, CHARLES, service department, General Motors Truck Co.

SKINNER, A. A., sales manager, Leece-Neville Co.

SMITH, C. H., district manager, B. F. Goodrich Co.

SMITH, M. A., assistant sales manager of the motorcoach division, Yellow Mfg. Sales Corporation

SNYDER, C. A., manager of the highway improvement department, Chicago Motor Club

SOUREY, W. D., K-P. Products Co.

SPARKAWK, C. O., service department, Twin Coach Co.

STANLEY, F. C., chief engineer, Raybestos Co.

STEARNS, E. A., salesman, Forest Electric Corporation

STEPHENS, E. S., sales engineer, Central Commercial Co.

STRAUB, JOSEPH C. A., engineer, International Harvester Co.

SWANSON, G. C., salesman, Chicago Auto Equipment Co.

SWIGART, J. T., regional service manager, The White Co.

TAPPING, W. G., sales department, Dodge Bros., Inc.

THEE, LIEUT. WALTER C., U. S. A., property and maintenance officer, Army motor service, Quartermaster Corps

TILT, A. B., superintendent of automobile transportation, Swift & Co.

THOMAS, F. H., agent, Chicago & Eastern Illinois Railway Co.

TIERNEY, J. W., sales engineer, Electric Storage Battery Co.

TOMPKINS, STEPHEN B., service manager, Mack-International Motor Truck Corporation

TREAT, DEAN, railway and motorcoach department, Standard Oil Co. of Indiana

TRUESDELL, S. R., transportation engineer, Yellow Truck & Coach Mfg. Co.

TURLEY, E. W., salesman, The Autocar Co.

UNDERWOOD, A. J., standards department, Society of Automotive Engineers, Inc.

VAN NESS, R. H., superintendent of transportation, City Ice Co.

VESTED, HARRY B., branch manager, The Trailmobile Co.

VIALL, ETHAN, editor, Motor Service Publishing Co.

WANAMAKER, E., electrical engineer, Chicago, Rock Island & Pacific Railway Co.

WARNER, JOHN A. C., assistant research engineer, Studebaker Corporation of America

WATERS, G. M., assistant sales manager, E. D. Kimball & Co.

WATROUS, JOHN H., Western representative, Ferodo & Asbestos, Inc.

WEAVER, E. W., automotive engineer, George T. Trundle, Jr., Engineering Co.

WHITTELSEY, C. B., Jr., assistant to the general manager, Society of Automotive Engineers, Inc.

WHITTEN, F. A., chief engineer, American Car & Foundry Motors Co.

WILKIN, ROBERT E., automotive engineer, Standard Oil Co. of Indiana

WILKINS, KENNETH M., student engineer, Chicago, North Shore & Milwaukee Railroad Co.

WILLIAMS, A. H., chief engineer, Shafer Bearing Corporation

WILLIAMS, H. R., sales manager, Wheeler-Schebler Carbureter Co.

WILSON, C. W., salesman, Electric Storage Battery Co.

WILSON, GUY W., engineer, General Electric Co.

WILT, GLENN A., salesman, Massillon Steel Casting Co.

WINCHESTER, J. F., superintendent of motor equipment, Standard Oil Co. of New Jersey

WINE, R. G., sales engineer, Firestone Tire & Rubber Co.

WOOD, E. C., superintendent of transportation and shops, Pacific Gas & Electric Co.

WOTTON, E. W., superintendent of equipment, Chicago Motor Coach Co.

WURTS, T. C., manager of heavy traction department, Westinghouse Electric & Mfg. Co.

YOUNG, O. W., sales manager, tractor and implement bearings, Hyatt Roller Bearing Co.

ZIEGLER, R. W., assistant general manager, International Tool Co.

ZIMMERMANN, F. A., representative, Handy Governor Corporation

The Maintenance Engineer

THE ideal maintenance engineer is one who looks upon technical knowledge and its application, not as his sole *raison d'être*, but as a means for increasing the earning capacity of the fleet and for reducing the cost of operation. This has sometimes to be done by the gradual acquisition of new vehicles to replace those which have become old in service rather than by clever and costly reconditioning of old models, and by taking full advantage of manufacturers' service and of facilities offered by outside specialists. In short, the business of the engineer is to keep the vehicles in good order by the aid of simple and inexpensive attentions, rather than by allowing wear to go on until it can be eliminated only by elaborate workshop processes which necessitate the maintenance of large staffs of mechanics and costly equipment.

The head of a transport concern must certainly possess sound engineering experience, but business training is equally important. Many of the most successful transport undertakings of today are controlled by general managers who, having had engineering training, have separated themselves altogether from all the details of technical work to concentrate upon the traffic and administrative sides. With such experience, the responsible head is able to act as adviser to both the chief engineer and the traffic superintendent, who, individually, have full control of their own departments. The general manager dictates all matters concerning policy and, having no personal leanings in favor of either branch of the business, is able to secure that essential coordination which otherwise is so difficult to attain.—*Modern Transport* (London).

Merchandising

SERVICE to the consumer is the secret of all lasting success. The records of business failures disclose this fact. Service to the consumer means proper financing, proper administration of the business details of a company, proper pricing and proper values as they relate to quality and style. It means the proper organization of overhead and the ability so to determine the buying market that the goods bought for resale are in accord with the buying demand of the ultimate consumer. To charge the consumer more than he is justified in paying for the service between the making of the goods and passing them over the counter is to impose upon him a tax which he will not bear.

The automobile industry, which in gross volume of sales is the largest in this Country, is an example of cutting down the costs between the manufacturer's price and the price paid by the consumer. Distributors and dealers function on a basis profitable to themselves yet with a difference between manufacturers' cost and list price to consumer, which is lower proportionately than in almost any other branch of retailing.—George Bruce in *Printers' Ink Monthly*.

ALBERT CHAMPION

WHILE on his customary annual visit to France in the interest of the A C Spark Plug Co., of which he was president, and to attend the Automobile Salon in Paris, Albert Champion died of heart trouble in a Paris hotel the night of Oct. 27. He had not been well for several days. Mrs. Champion was with him at the time. Although he had lived in the United States for many years and had built up large business interests in Flint, Mich., and was a resident of Pontiac, Mich., Mr. Champion never had been naturalized here.

At the time of becoming a member of the Society in October, 1911, Mr. Champion was first vice-president of the Champion Ignition Co., of Flint, which specialized in spark-plugs, magnetos and dynamos for motor-vehicles. Born in Paris in 1878, he attended high school and began his technical education there but left to come to the United States. He became noted as a bicycle racer in Europe. His first business connection was with the Waltham Mfg. Co., of Waltham, Mass., for which he imported Aster engines and carbureters from 1899 to 1902. During 1904 he was engaged in the experimental and testing department of the Packard Motor Car Co. Following a return for 10 months to Paris, Mr. Champion established himself in the manufacture of ignition apparatus in Boston in 1908. Later, he severed his connection with this enterprise and started the Champion Ignition Co., and subsequently the A C Spark Plug Co., now a division of the General Motors Corporation.

Mr. Champion was an enthusiastic member of the Society and a regular attendant at its meetings in earlier years. He and Mrs. Champion were members of the party that made the first S.A.E. European visit in 1910.

ROGER P. DESCHAMPS

AFTER a very short illness with pneumonia, Roger P. Deschamps died at the Knickerbocker Hospital in New York City on Oct. 6, 1927. The body has been sent to his parents in Belgium for interment there. He is survived in this Country by his widow, Mrs. Eleanor Deschamps, now in New York City.

Mr. Deschamps became an Associate Member of the Society in December, 1922. He was born in Dampreny, Belgium, in 1892, and received his education in mechanical and electrical engineering at the University of Louvain, from which he was graduated with the degree of engineer in 1914. From August, 1914, to May, 1919, he served as director of automobile repairs in the third division of the Belgian army. The succeeding 12 months he spent visiting the United States seeking lines of American automobiles and agricultural machinery to be sold in Belgium by the firm of Gustave Deschamps et Fils. From 1920 to the time of his death, he was manager of the Standard Automobile Co., of Brussels, Belgium. Besides holding membership in the Society of Automotive Engineers, Mr. Deschamps was a member of the American Institute of Mining and Metallurgical Engineers.

FRANK L. BROWN

WITH deep sorrow Vice-President T. F. Manville, of the Columbia Steel & Shafting Co., announces that Frank L. Brown, who was first vice-president of this Pittsburgh company and treasurer of the Edgar T. Ward's Sons Co., of Carnegie, Pa., died on Oct. 14 at the Metropolitan Hospital in Philadelphia, to which he had been removed after being taken ill in the Bellevue-Stratford Hotel.

Mr. Brown had been an Associate Member of the Society since September, 1920, at which time he was second vice-president of the Columbia Company, and he was also a member of the Iron and Steel Institute. He was born in Portsmouth, Ohio, in 1877, and had been engaged in the steel industry for 32 years, having been production engineer for the Republic Iron & Steel Co. from 1902 to 1911 and second vice-president in charge of production and traffic for the Standard Welding Co. from 1911 to 1913, when he took charge of the operating and engineering department and also of the traffic department of the Columbia Steel & Shafting Co.

Mr. Brown may be said to have been born into the steel industry, as his great grandfather was a member of the firm that built one of the Country's first blast furnaces at Portsmouth, Ohio, out of which grew the Brown-Bonnell Iron Co., which later removed to Youngstown, Ohio, and is now known as the Brown-Bonnell Works of the Republic Iron & Steel Co.

EDWARD JOSEPH DUNN

THE closing of a life of great activity and broad interests came with the passing away of Edward Joseph Dunn, president of the Eclipse Machine Co., of Elmira, N. Y., on Oct. 23, at the age of 61 years. Mr. Dunn had been active in the affairs of the company until recently and was able to confer with his business associates and friends until a few days before his death. He had been an Associate Member of the Society since 1917 and was widely known in the automotive industry, more especially of late years in connection with his promotion of the Bendix drive for electric engine-starters.

Mr. Dunn was a leading citizen of his native city, not alone as a manufacturer but also as a financier and philanthropist. He began his business life in 1881 as a clerk in the office of the Elmira Gas Light Co. and the Arnot Real Estate Co., where he remained for 5 years. He then entered the service of the Chemung Canal Bank as a bookkeeper but was promoted from time to time until, in 1903, when the Chemung Canal Trust Co. was organized, he was made treasurer. In 1919 he assumed the duties of president, which he performed for the next 6 years.

He was appointed a co-executor of the estate of M. H. Arnot, which included the business of the Eclipse Machine Co., then manufacturing coaster-brakes for bicycles and

motorcycles, and assumed active charge of the company. In addition to holding the presidency of this company at the time of his death, Mr. Dunn was president of the Eclipse Machine Co., Ltd., of Walkerville, Ontario; and the Eclipse Textile Devices, the Dunn Realty Corporation and the Dunn-Cooper Corporation, all of Elmira; and was a director of the Elmira Water, Light & Railroad Co., the Elmira Knitting Mills, the Shepard Electric Crane & Hoist Co., of Mountain Falls, the Johnson Oil Refining Co., of Chicago, and the American-La France Fire Engine Co.

Besides holding membership in the Society of Automotive Engineers, Mr. Dunn was a member of the Engineers Club of New York City, the Aviation Club of Detroit, and a number of business and recreation clubs and fraternal organizations. He was a liberal contributor to worthy charities without distinction of race, color or creed, and his passing is deeply mourned, not only in the community in which he was such an important figure, but in the wider circle of business friends with whom he had come in contact in the many fields of his activities.

HERBERT A. TEMPLE

FOLLOWING an illness of about 3 months, Herbert A. Temple, experimental engineer of the Hupp Motor Car Corporation, died at Detroit on Sept. 8, 1927. Mr. Temple was elected to the Society with the grade of Member in June, 1919, at which time he was a member of the engineering staff of the Pontiac Motor Car Co., with the duties of assisting the chief engineer in remedying manufacturing troubles and looking after experimental work and electrical equipment.

Mr. Temple was a native of New York State, as he was born at Seneca in 1883. He was graduated by Cornell University in 1906 with the degree of electrical engineer in mechanical engineering. From 1911 to 1914 he was in charge of all experimental and development work for the Sheffield Car Co., of Three Rivers, Mich. The following year he had charge of the experimental work and of the electrical equipment of cars for the Hupp Motor Car Corporation. From 1915 to 1917 he was chief engineer of the United Electrical Mfg. Co., at Adrian, Mich., for which he had charge of the designing of electrical equipment for automobiles. In 1918 he was for 3 months laboratory engineer for the Studebaker Corporation of America, in Detroit, and for 6 months was assistant superintendent of the experimental division of the Packard Motor Car Co. From 1918 to the time of his election to membership in the Society, he held the position of engineer with the Pontiac company, as stated, and subsequently rejoined the engineering staff of the Hupp Corporation.

Human Wants and Evolution

IT is wholly unwarranted to confuse economic forces with material forces. One tremendously important factor in economic life is human wants. These are all psychological in character, and they range from the want for books on philosophy and beautiful pictures to the desire for corn beef and cabbage. Moreover, while law and morals are often tremendously influenced by economic factors, they in turn react upon economic development in powerful ways. In England, for example, land ownership is concentrated in a few hands. In France it is widely diffused. In both countries it was highly concentrated at the time of the French Revolution. France then adopted the legal rule of compelling the division of estates equally among all the children of the family. England retained the law of primogeniture under which the oldest son inherited the land. This simple change in the French law has led to the present wide diffusion of land ownership in France.

I believe that it does make a tremendous difference what decisions human beings make; that human likes and dislikes, choices, approbations and disapprobations are vital factors in the course of history; and that within a considerable range there is real freedom of human choice in determining the course of human evolution, the limits being much more imposed by our ignorance and inability to cooperate than by any cosmic necessity or materialistic determinism.

The workingman understands plant and equipment, but does not visualize "good-will." The activity of making a living is only a part of the activity of man, and the basic things which human beings have in common bring them together far more than the modes of making a living pull them apart. Employer and employe share the great human crises and experiences, birth and childhood, adolescence, love-making, marriage, parenthood, the death of loved ones, the joys of friendship, the contagion of the crowd. As producers, we tend to develop different kinds of minds and social attitudes; on the other hand, as consumers, we tend more and more to become alike as machine production, which means inevitably mass production, makes headway.

Proportional Production

Increasing production of one commodity makes possible increasing consumption of other commodities. So long as commodities are produced in the proportions that meet the demands in the market, the economic process goes on smoothly. Overproduction of particular commodities with underproduction of others is easily possible and frequently occurs. Maladjustments in production are economic realities of a grave sort. Out of maladjustments of this kind crises can come, and do come. But there is no such thing as a general overproduction, and no such thing as a crisis growing out of general overproduction.

John Stuart Mill, writing in 1848, doubted whether all the labor-saving devices had lightened the burden of a single human being. But throughout Europe and the United States real progress was made, at an increasing rate, in improving life conditions. In the United States, since the check to immigration which the war brought and the legal immigration restriction since the war, the rise both in money wages and in real wages, wages measured in terms of the necessities and comforts of life, has been impressive.

Crises, instead of becoming more severe, are becoming more manageable. With better organization of our monetary and banking system, we have eliminated the old-fashioned financial panic. Business crises, periods of liquidation and adjustment we have not eliminated, but within the last few years we have seen the growth of a business policy, that of hand-to-mouth buying and limited commitments and careful adjustments of production to the markets, which promises much toward mitigating the violence of up-and-down swings.—B. M. Anderson in *Chase Economic Bulletin.*